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(54) **COMBINED SUBTRACTIVE INTERFERENCE CANCELLATION AND SPACE DIVERSITY SIGNAL PROCESSING IN A CELLULAR CDMA COMMUNICATIONS SYSTEM**

KOMBINIERTE SUBTRAKTIVE STÖRUNGSUNTERDRÜCKUNGS- UND RAUMDIVERSITYSIGNALVERARBEITUNG IN EINEM ZELLULAREN CDMA-NACHRICHTENÜBERTRAGUNGSSYSTEM

ELIMINATION D'UNE INTERFERENCE PAR SOUSTRACTION COMBINEE A UN TRAITEMENT DE SIGNAUX DE DIVERSITE D'ESPACE DANS UN SYSTEME CELLULAIRE DE COMMUNICATIONS AMCR

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(56) References cited:
EP-A- 0 491 668
WO-A-95/19078
US-A- 5 151 919

- **LIU T -C: "The modular covariance adjustment adaptive array for CDMA wireless communications" ICASSP-93. 1993 IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING (CAT. NO.92CH3252-4), ICASSP '93. IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH AND SIGNAL PROCESSING, MINNEAPOLIS, MN, USA, 27-30 APRIL 1993, ISBN 0-7803-0946-4, 1993, NEW YORK, NY, USA, IEEE, USA, pages 180-183 vol.4, XP000437039**

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Description

Field of the Invention

[0001] The invention relates to a communication system and provides improved capacity in cellular wireless telephone systems using Code Division Multiple Access methods together with base station receiving systems employing antenna arrays.

Background of the Invention

[0002] The cellular telephone industry has made phenomenal strides in commercial operations in the United States and throughout the reset of the world. Growth in major metropolitan areas has far exceeded expectations and is outpacing system capacity. If this tend continues, the effects of rapid growth will soon even reach the smallest markets. Innovative solutions are required to meet these increasing capacity needs as well as maintain high quality service and avoid rising prices.

[0003] Currently, channel access is achieved using Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) methods. With FDMA or TDMA systems or hybrid FDMA/TDMA systems, the goal is to insure that two potentially interfering signals do not occupy the same frequency at the same time. In contrast, CDMA allows signals to overlap in both time and frequency. Thus, all CDMA signals share the same frequency spectrum. In either the frequency or the time domain, the multiple access signals appear to be on top of each other. In principal, the informational data stream to be transmitted is impressed upon a much higher bit rate data stream generated by a pseudo-random code generator. The informational data stream and the high bit rate data stream are combined by multiplying the two bit streams together. This combination of the higher bit rate signal with the lower bit rate data stream is called coding or spreading the informational data stream signal. Each informational data stream or channel is allocated a unique spreading code. A plurality of coded information signals are transmitted on radio frequency carrier waves and jointly received as a composite signal at the receiver. Each of the coded signals overlaps all of the other coded signals, as well as noise-related signals, in both frequency and time. By correlating the composite signal with one of the unique codes, the corresponding information signal is isolated and decoded.

[0004] There are a number of advantages associated with CDMA communication techniques. The capacity limits of CDMA-based cellular systems are projected to be up to twenty times that of existing analog technology as a result of the properties of a wide band CDMA system, such as improved coding gain modulation density, voice activity gating, sectorization and reuse of the same spectrum in every cell. CDMA is virtually immune to multi-path interference, and eliminates fading and static to enhance performance in urban areas. CDMA transmission of voice by a high bit rate decoder insures superior, realistic voice quality. CDMA also provides for variable data rates allowing many different grades of voice quality to be offered. The scrambled signal format of CDMA completely eliminates cross talk and makes it very difficult and costly to eavesdrop or track calls, insuring greater privacy for callers and greater immunity from air time fraud.

[0005] U.S. Patent No. 5,151,919 describes a Code Division Multiple Access system in which overlapping signals coded using different access codes are received at a receiving system and decoded in order of decreasing signal strength, subtracting stronger signals after they are decoded and before attempting decoding of weaker signals. The patent discloses a preferred method of subtraction involving transforming the received signal to a symbol-space domain to identify the symbol most likely transmitted, and then setting to zero the value identified with the symbol in the symbol-space domain, thus removing that signal. An inverse transform returns the residual values to the original domain for iterative processing by performing a transform to the symbol-space of the next signal to be decoded, and so-on.

[0006] U.S. Patent No. 5,353,352 discloses how to form access codes suitable for discriminating different mobile transmissions on the same frequency, suitable for use with subtractive demodulation.

[0007] U.S. Patent No. 5,218,619 describes an improved method of subtractive demodulation wherein a second subtraction of a previously subtracted signal is performed after subtracting other intervening signals, in order to cancel residual errors left from the first subtraction caused by the original presence of the intervening signals.

[0008] Neither of the above-incorporated patents discloses performing a two-dimensional transform from an antenna-space/time domain to a symbol-space/direction-of-arrival domain. The above-incorporated patents are relied upon to provide background art to the technique subtraction demodulation of coded signals and for performing signal subtraction by nulling in a transform domain.

[0009] U.S. patent No. 5,619,503 discloses various ways of employing an antenna array for receiving multiple signals from different directions using the same frequency bandwidth. Mathematical transforms involving matrix operations are disclosed, whereby a signal received from a given direction may be discriminated while simultaneously nulling interfering signals received from other directions. Thus, several signal transmissions may share the same frequency

bandwidth provided that the transmitters' directions relative to the receiving antenna are sufficiently different. When the directions of two transmitters almost coincide, the matrix solution becomes undefined and the transmitters can not be discriminated. An alternate method is disclosed for such cases, whereby, instead of attempting to separate signals by matrix-combining the signals from the antenna elements, a symbol received from each transmitter is hypothesized, and the expected corresponding received signals at each antenna element are computed using direction of arrival estimates. The sum of signals expected at each antenna element is compared with the actual value at each antenna element and the squared differences used to form a metric indicative of the probability that the symbol hypotheses are correct. A maximum likelihood processor then identifies that hypothesis that has highest probability of being correct. The complexity of such a maximum likelihood processor is proportional to two-to-the-power of N, where N is the number of overlapping signals.

[0010] U.S. patent No. 5,790,606 discloses using an array of antenna elements to receive signals from a plurality of transmitters using the same frequency with a maximum likelihood processor operating sequentially along a spatial dimension, being the dimension along which antenna elements are spaced, the maximum likelihood processor complexity being much less than proportional to 2^N and proportional instead to 2^M, where M is only as large as the subset of antenna elements that receive significant signals strengths from the same transmitter. Thus, the antenna element signals are not transformed into directively received signals corresponding to different transmitter directions, but rather different transmitter signals are transformed into expected antenna element signals.

[0011] The above mentioned patents are relied upon to supply background on the state of the art using antenna arrays for improved reception of multiple signals using the same frequency channel.

Summary of the Invention

[0012] The object of the invention is to provide a communications system and a method which provide greater communications capacity or quality. This object is solded by a communications system according to claim 1 or by a method according to claim 33. Further advantageous embodiments and improvements are listed in the dependent claims.

[0013] The invention to be described below in accordance with one aspect is an improvement upon the above prior art when utilizing subtractive demodulation of coded signals simultaneously with the use of antenna arrays to provide directive discrimination. The invention differs from using prior art antenna arrays to provide directive beams and then processing the signal from a directive beam using subtractive demodulation. Such a combination is considered anticipated in the incorporated references. In the invention, when a signal is decoded and subtracted, it is subtracted from all antenna element signals and therefore vanishes not only from the directive beam it is received in, but also vanishes from all other beams formed using the same antenna elements, even when those other beams have substantial spatial overlap with the signal's beam.

[0014] Mobile phones transmit coded signals to at least one base station. The base station in according with the invention is equipped with an antenna array for receiving signals from a plurality of mobiles stations lying in different directions, the signals transmitted by the mobile stations comprising information symbols chosen from an orthogonal alphabet, further scrambled using an access code.

[0015] Signals from the antenna array elements comprising weighted sums of the signals transmitted by different mobile stations are amplified, downconverted filtered and digitized to form corresponding streams of numerical samples that are fed to a processor including means for storing numerical samples and means for performing arithmetic operations on stored samples. The processor arranges samples received sequentially in time from different antenna elements in a two-dimensional array, one dimension corresponding to the different antenna elements and the other dimension corresponding to time, i.e. sequence of reception, hereinafter referred to as the space/time domain.

[0016] The numerical samples are unscrambled using the access code of a first mobile transmitter and the processor then computes a two-dimensional transform of the two-dimensional array of unscrambled samples to produce a two-dimensional array of result-bins, wherein bins along one dimension correspond to the symbols in the alphabet and bins in the other dimension correspond to combinations of samples received via different antenna elements thus providing directive receiving beams in different directions, the result-bins hereinafter referred to as the code/space domain.

[0017] The processor identifies the result-bin containing the greatest value and thereby identifies a symbol received from the first mobile and a direction of reception. The value of the bin is then set to zero and an inverse two dimensional transform is performed to transform the residual bin values back to the space/time domain, the just-identified signal having been subtracted out. The samples are then rescrambled using the first mobile's access code.

[0018] The process then repeats starting with descrambling using a second mobile's access code, and so forth, until a symbol has been decoded from all mobile transmitters. The entire process then repeats for sequential symbol periods to construct a sequence of received symbols from each mobile transmitter.

[0019] The access codes of the first mobile, second mobile etc. preferably belong to mobiles selected in order of decreasing signal strength such that the strongest mobile signals are decoded and subtracted out before decoding weaker mobile signals, thereby providing improved discrimination of overlapping signals by both access code and

direction of arrival, and thus allowing a greater number of transmissions to share the same frequency bandwidth.

[0020] According to another aspect of the present invention, a communications system is disclosed comprising a plurality of mobile stations and an improved base station for receiving signals from said mobile stations and decoding information-bearing signals transmitted therefrom. An antenna means comprising antenna elements disposed around a support structure receives signals transmitted from said plurality of mobile stations and generates output signals from each antenna element. Conversion means amplify, filter and convert signals from each of said antenna elements into a corresponding number of converted signals for processing. Storage means temporarily store a number of samples of said converted signals. Processing means iteratively process and reprocess said stored samples successively to decode said information from each of said mobile stations in turn. The processing provided by said processing means identifies from said stored samples an information symbol transmitted by one of said mobile stations thereby decoding said information-bearing signal, and subtracts values dependent on said identified information symbol from said stored samples thereby reducing interference between the just-decoded signal and the signal to be decoded at a subsequent iteration.

[0021] According to yet another aspect of the present invention, a communications system is disclosed comprising a plurality of mobile stations and an improved base station for receiving signals transmitted from said mobile stations each with the aid of an assigned access code and for decoding information symbols belonging to an allowed alphabet of symbols encoded in said transmissions. Antenna means comprising antenna elements disposed around a support structure receive signals transmitted from said plurality of mobile stations and generate output signals from each antenna element. Conversion means amplify, filter and convert signals from each of said antenna elements into a corresponding number of converted signals for processing. Storage means temporarily store a number of samples of said signals converted from each of said antenna elements at successive instants in time. Two-dimensional numerical transform means process said stored samples using one of said access codes assigned to a first one of said mobile stations to produce a two-dimensional array of transformed samples, said transformed samples lying along one dimension of said two-dimensional array corresponding to different possible directions of arrival of signals at said base station transmitted by said first mobile station and transformed samples lying along the other dimension of said two-dimensional array corresponding to correlations with different ones of said information symbols in an allowed alphabet of symbols.

[0022] According to still another aspect of the present invention, a communications system is disclosed comprising a plurality of mobile stations and an improved base station for receiving signals transmitted from said mobile stations each with the aid of an assigned access code and for decoding information symbols belonging to an allowed alphabet of symbols encoded in said transmissions. Antenna means comprising antenna elements disposed around a support structure receive signals transmitted from said plurality of mobile stations and generate output signals from each antenna element. Conversion means amplify, filter and convert signals from each of said antenna elements into a corresponding number of converted signals for processing. Storage means temporarily store a number of samples of said signals converted from each of said antenna elements at successive instants in time. Two-dimensional numerical transform means process said stored samples using one of said access codes assigned to a first one of said mobile stations to produce a two-dimensional array of transformed samples, said transformed samples lying along one dimension of said two-dimensional array corresponding to different possible directions of arrival of signals at said base station transmitted by said first mobile station and transformed samples lying along the other dimension of said two-dimensional array corresponding to correlating samples with different ones of said information symbols in an allowed alphabet of symbols using a prescribed time-shift between the samples correlated and said information symbols. Means repeat said two-dimensional transform for a plurality of said time-shifts corresponding to delayed reception of signals from said first mobile station corresponding to delayed echoes of said signals caused by signals reflection from objects in the propagation path.

Brief Description of the Drawings

[0023] These and other features and advantages of the invention will be readily apparent to one skilled in the art from the following written description, used in conjunction with the drawings, in which:

Figure 1 illustrates a prior art transmitter for use with the present invention;
Figure 2 illustrates an array antenna for use with the present invention;
Figure 3 illustrates a space/code processor according to one embodiment of the present invention;
Figure 4 illustrates ray processing for time-of-arrival and direction-of-arrival combinations according to one embodiment of the present invention; and
Figure 5 illustrates Butler Matrix/Fourier Transform formulation of beamforming according to one embodiment of the present invention.

Detailed Description

[0024] Figure 1 illustrates a simplified block diagram of the type of mobile transmitter the current invention is designed to decode. The transmitter is a prior art transmitter of the same form disclosed in the incorporated documents.

[0025] A speech signal from a microphone 10 is digitized and compressed using a speech coding algorithm in a speech encoder 11 to produce a digital bitstream representative of the speech signal. Existing digital cellular systems have compressed the speech signal to bitrates of 13KB/s (GSM) and 7KB/s (IS54) respectively, and at the state of the art acceptable speech quality can be maintained even with speech coders that reduce the bitrate to 3.6KB/s.

[0026] The bitrate from the speech encoder may be increased again by the use of error correction encoding. Most redundancy is added to protect the most perceptually important bits while the least perceptually important bits may not be coded at all. Such coding, if any, is considered to be part of block 11 in Figure 1. The resulting encoded digital speech from block 11 is formed into multi-bit symbols for spread-spectrum encoding in block 13. For example, 7-bit blocks can be formed and each of the 128 possible 7-bit patterns is represented by one of 128 orthogonal Walsh-Hadamard codes, thus expanding the bitrate further by a factor of 128/7. When such block-orthogonal spread-spectrum symbol coding is employed, a preferred form of error correction coding within speech encoder 11 is Reed-Solomon coding, which is adapted to code multi-bit symbols. The combination of Reed-Solomon coding and Walsh-Hadamard coding can be done in a variety of ways to produce unequal coding for the most and least perceptually significant bits. For example, a Reed-Solomon code constructed on a GF2**7 can code a block of 7-bit important symbols to produce an RS-coded block containing a greater number of symbols. A "Galois Field or GF is the set of all integers from 0 to some maximum that is a closed set under some modulo combinatorial operations. A GF2**7 (two to the power of seven or $GF2^7$) means all integers from 0 to 127, i.e., all 7-bit binary codes. If two of these are combined by 7-bit wide XOR (modulo-2 addition) an other 7-bit value in the set results, so the set is "closed" under the combinatorial operation "XOR". The remaining less important symbols can be formed into 7-bit blocks but not RS coded. The RS-coded and the non-RS-coded 7-bit symbols are then output from the encoder 11 to the Walsh-Hadamard encoder 13, the bit-to-symbol formation 12 having already been performed inside the encoder 11 in this case, at least for the RS-coded symbols.

[0027] An alternative unequal coding method is to form important bits into, for example, 5-bit symbols which are then RS-coded on a GF2**5 to form a larger block of RS-coded 5-bit symbols. Two bits of lesser importance are then added to each 5-bit RS symbol to obtain 7-bit symbols which are then submitted to Walsh-Hadamard coder 13 to obtain 128-bit codewords.

[0028] To provide privacy for individual conversations, encryption can be added either in block 11 or in block 12 as described in U.S. Patent No. 5,353,352.

[0029] Different mobiles produce Walsh-Hadamard codes from the symbol encoder 13 belonging to the same set of 128 codes, and thus to aid discrimination between different mobiles, an access code is bitwise modulo-2 combined with the codewords at block 14, as described in U.S. Patent No. 5,353,352. The access codes are preferably chosen such that an access-coded codeword of one mobile transmitter is maximally different from all 128 possible access-coded codewords produced by any other mobile transmitter.

[0030] For simplicity, details that are not material to the current application are omitted from Figure 1, such as addition of signalling information to speech information, source of encryption keys, and overall control of the transmitter by a control processor is not shown.

[0031] The access-coder 14 produces 128 bits out that are converted to a serial stream if necessary for modulating the radio-frequency carrier by a serializer 15. The bit stream is applied to a modulator 16 to produce a modulated RF signal which is then amplified to a transmit power level in a power amplifier 17 for transmission using an antenna 18. For simplicity, the corresponding mobile receiver circuits that use the same antenna for receiving are not shown.

[0032] Figure 2 illustrates the connection of a cylindrical antenna array 21, such as is described in U.S. patent No. 5,619,503 to the inventive processor 60 of the current invention.

[0033] Antenna elements 22 are arranged in collinear columns 20 and the columns 20 are disposed around a cylinder 21 atop an antenna mast at a cellular base station site. The elements of a column are coupled so as to form column signals 23 and each such collinear column exhibits directivity in the vertical elevation plane but a broad beamwidth in the horizontal (azimuth) plane. Each column signal is processed by a receiving channel 31 forming a bank of channels 30. Each channel 31 comprises for example a first RF filter 310; a low noise amplifier 311; a second RF filter 312; a downconvertor 313 using a common local oscillator 32; an Intermediate Frequency (IF) filter 314; an IF amplifier 315 and a complex AtoD convertor 316 to generate a stream of complex numerical samples 36 representative of the RF signal from each collinear column of elements.

[0034] The AtoD convertor can comprise quadrature downconversion using I,Q mixers and I,Q AtoD convertors, or alternatively can employ the logpolar digitization technique described in U.S. Patent No. 5,048,059.

[0035] The complex digital outputs 36 are then fed to the processor 60 which includes a space/code processor 40 to discriminate and output separate symbol streams received from each mobile transmitter (Figure 1) and a bank 50

of individual traffic channel processor units to process the symbol streams for each traffic channel to regenerate speech signals, signalling and control information or user data such as fax or computer data signals.

[0036] Figure 3 illustrates part of space/code processor 40 comprising a two-dimensional numerical transform. Signals received from the set of antenna columns at the same time (t1) form a row of input signals to a beamforming matrix 70 for tl. The set of antenna signals received at successive time instants t2, t3....t128 are fed to a corresponding number of identical beamforming matrices 70. It shall be understood that all signals processed by the two-dimensional transform are complex numbers, having a real part and imaginary part each represented as fixed or floating point binary values. In general, fixed point representations are preferable as the hardware required to process fixed point numbers is less expensive.

[0037] The beamforming matrices compute a set of output signals each corresponding to having formed a directive beam in a particular direction in azimuth. The number of beams computed for each sampling instant t(i) is typically equal to the number of antenna columns, such that the beamforming matrix corresponds to a multiplication of a row of input values by a square matrix of complex beamforming coefficients. Numerical beamforming and efficient methods therefor are described in U.S. patent No 5,909,460 entitled "Efficient Apparatus For Simultaneous Modulation and Digital Beamforming For an Antenna Array".

[0038] Through the beamforming matrix, a signal arriving from a particular direction corresponding to a beam direction is enhanced relative to signals arriving from other directions. The beamformer computes beams covering the ensemble of directions and so all signals are enhanced in one or another of the beams. As will be discussed below, the beamformer does not necessarily however compute beams for all signals at the same time, as it preferably makes fine beam direction adjustments individually for each mobile signal.

[0039] The beam signals for beam direction 1 computed for successive time instants t1,t2... t128 form a 128-complex-valued input vector to Fast Walsh Hadamard Transform (FWT) processor 71 for beam 1 and likewise the set of signals for beam 128 computed for successive sampling instants t1 .... t128 form the input vector to FWT processor 71 for beam N. The FWT processors for all other beams are also performed, yielding an array of 128 x N two-dimensionally transformed results, the first dimension of the transform being antenna-element/beam-space and the second dimension being time/code-space. Each FWT processor transforms 128 input values to 128 output values and can be constructed using fully parallel logic to operate extremely rapidly, as described in U.S. Patent No. 5,357,454 to applicant, which is hereby incorporated by reference in its entirety herein.

[0040] In Figure 3, for simplicity, it is assumed that the operation of descrambling the set of 128 input values using an access code assigned to a particular mobile signal is included as the first step inside FWT processor 71. This step undoes the step performed by the corresponding scrambler 14 of Figure 1. The access code is chosen first to be that assigned to a mobile transmitter previously identified with the strongest signal received at the base station. A symbol transmitted by that transmitter will result in a corresponding one of 128 FWT processor outputs from one of the N beam-associated FWT processors 71 being the largest output. The beam in question should not change rapidly between one symbol and the next, a period of typically a fraction of a millisecond, because the mobile transmitter does not circulate around the antenna array with such a huge angular velocity. Therefore the beam to use for identifying a transmitted symbol may be predicted from previous results, and after identification of the transmitted symbol, the value in the same symbol bin in other beams can be examined to determine if the signal is growing in another direction-bin; at some point, if the mobile transmitter is moving, the signal in another beam/direction-bin would become larger and then the beam for decoding that mobile would be changed. In an intermediate phase, when the mobile straddles two beams and thus produces similar results from two neighboring sets of 128 outputs, the weighted sum of the two sets of 128 outputs may be used for decoding the symbol.

[0041] Decoding a symbol comprises identifying the index of the largest of the 128 values of the above-mentioned sum, or of 128 FWT processor outputs of a single beam. This may be done extremely rapidly using fully parallel logic, as described in U.S. Patent No. 5,187,675.

[0042] Having identified the index of the largest value, that value is set to zero in the 128-value array for the beam (or beams, if more than one are summed) used for decoding. Thus, out of the 128 x 8 space/code domain values computed by the space/code processor, one value (or perhaps two) are set to zero. The remaining values are then inverse transformed using Figure 3 in reverse, namely an inverse FWT is performed on columns of values, they are rescrambled using the same access code, and then rows of values are multiplied by a matrix inverse of the beamforming matrix to obtain 128 x N values once more in the space/time domain.

[0043] Because the beam from which the signal was decoded was predicted in advance, it will be realized that beamforming matrices 70 did not need to compute beam signals for all the beams, but only for that in which the signal is predicted to be received strongest plus perhaps the beams lying on either side, in order to monitor for the signal crossing to an adjacent beam due to transmitter movement. The FWT processors 71 do not then have to be performed for the beam signals that are not computed. However, in order to be able to reverse the beamforming process 70, the number of output values computed must be equal to the number of input values, i.e. the beamforming matrix must be square and therefore information-lossless. However, it may be possible to simplify the matrix multiplication by using a

matrix containing many zeros in rows corresponding to uncomputed beams, as long as the inverse of the matrix still exists and rows corresponding to the needed beams comprise the correct beamforming coefficients. Since completely different matrices and inverses would then need to be precomputed and stored for each signal direction, it may be better to use a single matrix and to not be concerned about the wasted effort in computing unneeded beams. The unneeded FWTs are still saved if the corresponding beams are not needed to decode a signal.

[0044] Now, the signals received from different mobile transmitters do not necessarily have their 128-sample symbol periods exactly aligned. Moreover, the signal sampling performed in the AtoD convertors 316 is not necessarily synchronous with the center or an optimum sampling point of every symbol. Indeed the signal from any particular mobile transmitter may be received with time-smear due to the phenomenon known as multipath propagation whereby reflections of the signal from tall buildings, hillsides and such are received with different delays that can be many sample-periods delayed, each delayed version of the signal being called a "ray". Sample timing misalignment, whereby sampling occurs between two code chips, also gives rise to ray-splitting, whereby a correlation is observed for the two chip-shifts straddling the correct sampling point. The aforementioned references explain how to handle all these effects by computing FWTs also for 128-sample vectors that are shifted in time to account for the delay of a particular echo. FWT vectors for each shift are added with complex weights accounting for the phase shift and attenuation of each path to obtain a combined signal for decoding. The chip-shifts that are selected for combining using complex weighted addition are called "RAKE taps", and the coefficients are called "RAKE coefficients". The combining of FWTs with complex weights may be simplified by restricting the RAKE coefficients to comprise real and imaginary parts that are inverse powers of two, which involves an acceptable loss compared to using exact complex weighting values. Multiplications by inverse powers of two are simple to implement by time-delaying bit-serially presented binary values, as described in U.S. Patent No. 5,305,349 entitled "Rake Receiver with Quantized Coefficients".

[0045] Figure 4 illustrates the arrangement for carrying out 2-dimensional transforms on different chip-shifts (RAKE taps) and also how unneeded FWTs may be omitted. The input buffers 72 receive AtoD converted sample streams from each antenna channel 31 and clock the samples into 128+L storage locations for each channel. The extra "L" locations corresponds to the amount of timing spread expected, expressed in chip periods, between the timing alignment of 128 chips of the latest Walsh code to be received relative to the earliest, the spread being either between two different mobile transmitters located at different distances from the base station or between two different rays that have propagated over different length paths. Corresponding ones of the 128+L buffered sample values from N antenna channel, are connected to an N-input, N-output beamforming matrix and transformed to produce N beam values. The 128+L values output from the beam in which a particular ray of a particular signal is expected to lie are then subject to a selection of those 128 that correspond to a particular timing alignment for a 128-chip Walsh code. The prediction of the beam and the timing of a particular ray is made by a channel tracker 73 which keeps track of the values of maximum correlations for beam directions on either side of the nominal direction of arrival as well as correlations with time shifts on either side, i.e. one chip early and one chip late, of the nominal expected time of arrival. The channel tracker 73 also keeps track of the mean complex value of maximum correlations averaged from one Walsh-Hadamard symbol period to the next, which yield the RAKE coefficient weights for combining different rays. The 128-point Walsh spectrum output from each FWT for a ray of a particular signal is weighted with the complex conjugate of the expected value produced by the channel tracker 73 and added with 128-point weighted vectors for all other rays for the same signal. Each ray has its own timing and may lie in a different beam from other rays of the same signal. Thus, the RAKE combining can combine a set of Walsh correlations for a direct ray received from the South with another set received L chips later from the North, being for example a signal reflection from a large building or mountainside. The channel tracker determines which of the times-of-arrival combined with which directions-of-arrival contain the most energy and combines these signals using for example the aforementioned inventive RAKE combiner having quantized coefficients. The combined signal, due to the complex conjugate weightings, should have its resulting values rotated into the real plane and thus the maximum of the 128 results' real parts is determined by a maximum search circuit 74. In Figure 4, block 74 also comprises accumulation of the 128-Walsh spectra for all rays using the weighting coefficient supplied by the channel tracker 73. When the largest value has been found, its value is returned to the channel tracker to update the coefficient in time for the next symbol period. The channel tracker will also determine whether that ray shall be used next time or whether another ray has become larger. Implicitly, the circuit of Figure 4 computes FWTs also for time-of-arrivals and direction-of-arrivals that are not presently significant and therefore do not contribute to the weighted sum, but which are computed in order to determine when or if one of them grows to become greater than one previously contributing to the sum, at which point the larger one will replace the smaller one.

[0046] Figure 4 shows the connections for selecting the RAKE tap or time-of-arrival represented by buffered samples L+1 to 128+L, i.e. the latest possible time-of-arrival. All 128+L time-of-arrivals are shown connected to beamforming matrices, although it is possible to omit beamforming matrices for the time-of-arrivals not used, i.e. for samples 1 to L. Only outputs from beamformers L+1 to 128+L are subjected to an FWT. In this case, the ray of time-of-arrival L+1 is anticipated to be received from direction "k", so only outputs "k" from beamformers L+1 to 128+L are connected to the 128-input FWT 71 to produce a 128-point Walsh spectrum output. This is accumulated in 128 bins in block 74 with the

Walsh spectra for all other significant rays, using a weighting coefficient from channel tracker 73. When all rays have been processed, block 74 determines the largest accumulated value and outputs its index as the decoded symbol, and returns the value to the channel tracker. The sequence of 2-dimensional transforms corresponding to each ray is then repeated, to reproduce the FWT values that were accumulated, and after each FWT is reproduced, the value corresponding to the decoded symbol index is set to zero and the inverse FWT performed on the residual values. Then the inverse of the beamforming matrices are applied to return the modified values to input buffers 72 once more. After the just decoded signal has been removed from the buffered values for all significant rays (each defined by a direction-of-arrival plus a time-of-arrival) that signal has vanished from the picture and thus does not interfere with signals subsequently decoded.

[0047] In the incorporated references, a preferred way to select the 128-samples from an input buffer 72 corresponding to a particular time-of-arrival is disclosed to be by use of a barrel shifter. A barrel shifter is an efficient way to shift a set of 128 taps up or down across a 128+L set of available tap selections. The desired shift "j" between O and L is expressed as a binary integer

$$jo + 2 \cdot j1 + 4 \cdot j2 + 8 \cdot j3$$

as an example where the maximum value L is 15.

[0048] A first stage of the barrel shifter selects 135 taps to comprise either the sample values 1 to 135 or 9 to 143 according as the value of binary digit j3 is 0 or 1. The 135 selected values are then subjected to further selection of 131 values to be either previously selected values 1 to 131 or 5 to 135 according as the value of j2 is 0 or 1. Then those 131 values are subjected to a further selection of 129 values to be either previously selected values 1-129 or 3-131 according to j1. Finally, jo determines whether previously selected value numbers 1 to 128 or 2 to 129 are selected. The advantage of this approach is that the total number of switch positions is approximately $2{*}128\log_2(L)$ compared with 128L for 128, L-pole switches, a reduction of approximately 2:1 in complexity for L=15 and greater savings for larger values of L.

[0049] It has thus been described how a first signal is decoded and subtracted. After each iteration, a symbol is decoded for a particular mobile and then the access code is changed to be that of the next strongest mobile signal and a new iteration performed. After decoding each signal, the largest value indicative of the symbol is saved. Its complex value is a measure of the phase and amplitude of that signal, and the complex value is averaged in a channel tracker as described in the incorporated references in order to determine in which plane the signal phase lies, and thus to be able to effect coherent detection of the symbol. The magnitude of the tracked value can also be used to predict the signal strength order for the next 128-sample symbol interval and thus to effect re-adaptation of the order of processing to account for different fading on different signals, such that decoding in descending signal strength order is maintained.

[0050] The index of the largest FWT component identified after combining all RAKE taps provides the index of the FWT component to be set to zero on the signal subtraction cycle. The machine of Figures 3 and 4 thus preferably comprises at least the two distinct phases of:

Detection phase: Calculate FWTs for the time-of-arrival and direction-of-arrivals of rays predicted by the channel tracker from past history to contain significant energy, accumulating the FWTs in 128 bins using channel-tracker-supplied weighting coefficients Then determine the index of the largest accumulated value.

Subtraction phase: Recalculate the same FWTs as above, in descending order of ray strength, and set to zero the component of each with the above index before inverse 2-dimensional transforming the residual values to obtain modified values for performing the next 2-dimensional transform for the ray of next lowest ray strength.

In addition, a third phase which may be termed "search phase" comprises:

Search phase: Perform a 2-dimensional transform for at least one other time-of-arrival and or direction-of-arrival not used in the detection and subtraction phases in order to detect the imminent growth of rays which should in the future be used in detection and subtraction.

In the incorporated references, it is also taught that a fourth phase, termed "reorthogonalization," can be desirable, in which, after processing other signals through phases of detection, subtraction and search, a previous signal-access code is re-used and a new subtraction phase is performed for the previous signal using an already determined index. In other words, the detection phase is omitted because the index of the current symbol is already known. The purpose

of the reorthogonalization phase is to reduce residual errors left from a previous signal subtraction phase due to errors in the amount subtracted caused by the presence of other signals. Those errors are proportional to the strengths of the other signals, but correlated with the first signal. After removing the other signals causing the error and therefore originally making it, the error can be detected by performing a new correlation using an FWT. A new subtraction phase then removes the error.

[0051] A preferred formulation of the beamforming operation will now be described. A signal incident on the array of ray strength s will result in a vector $\underline{V}$ of antenna column signals 23 of

$$\underline{V} = \begin{matrix} s.a1 \\ s.a2 \\ . \\ . \\ s.a(n) \end{matrix} = \begin{bmatrix} a1 \\ a2 \\ . \\ . \\ a(n) \end{bmatrix} . s = \underline{A} . s$$

where $\underline{A}$ is a column vector of the complex values a(i).

[0052] How much of the column signal is attributed to s and how much is attributed to the antenna channel gain factors a(i) is somewhat arbitrary, so for reasons that will become clear it is chosen to normalize the values of a1...a(n) such that

$$|a1|^2 + |a2|^2 \ldots\ldots + |a(n)|^2 = 1$$

To produce a beam that optimally combines the energy from each element to produce maximum directivity towards the signals source of S, the combining weighting coefficients should be equal to the complex conjugates of a(i), that is the combined signal should be

$$[a1^*,\ a2^*,\ a3^* \ldots . a(n)] . \begin{bmatrix} a1 \\ a2 \\ . \\ . \\ a(n) \end{bmatrix} . s \quad = \underline{A}^{\#} . \underline{A}\ s$$

where * signifies complex conjugate and # signifies conjugate transpose.

But

$$\underline{A}^{\#} . \underline{A} = |a1|^2 + |a2|^2 \ldots\ldots + |a(n)|^2$$

which has been set equal to 1 above. Therefore the result is simply s, indicating that s can be equated with the total signal energy intercepted by the array.

[0053] The beam forming matrix B must therefore contain a row equal to $\underline{A}^{\#}$ for the beam needed for receiving S. As yet, the other rows of B are not-defined, but will become so shortly after we impose the additional requirement that, after setting to zero the component in S's beam and multiplying by the inverse of B, the signal S shall have vanished from all antenna element values.

[0054] Thus multiplying the vector of received signals $\underline{V}$ by the beamforming matrix B yields

$$B.\underline{V} = \begin{bmatrix} s1 \\ s2 \\ . \\ s \\ . \end{bmatrix}$$

where "s" is the desired signal ray and s1,s2 correspond to other signals or mixtures thereof. Setting to zero the output corresponding to S is the same as subtracting the vector

$$\underline{S} = \begin{bmatrix} 0 \\ 0 \\ \cdot \\ \cdot \\ s \\ \cdot \\ \cdot \\ 0 \end{bmatrix} \text{ from the result.}$$

After multiplying by the inverse of B, we then get

$$B^{-1} \cdot ((B \cdot \underline{V}) - \underline{S}) = \underline{V} - B^{-1} \cdot \underline{S}$$

which should be equal to zero if B^{-1}. $\underline{S}$ cancels the components of S at all antenna elements.

[0055] Therefore

$$B^{-1} \cdot \begin{bmatrix} 0 \\ 0 \\ \cdot \\ s \\ \cdot \\ \cdot \end{bmatrix} = \begin{bmatrix} a1 \\ a2 \\ a3 \\ a(i) \\ \cdot \\ a(n) \end{bmatrix} \cdot s \quad or\ B^{-1} \cdot \begin{bmatrix} 0 \\ 0 \\ \cdot \\ 1 \\ \cdot \\ 0 \end{bmatrix} = \begin{bmatrix} a1 \\ a2 \\ a3 \\ \cdot \\ \cdot \\ a(n) \end{bmatrix}$$

[0056] The above shows that the column of B^{-1} corresponding to the beam of signal S is equal to the vector of coefficients a(i).

[0057] Since $B \cdot B^{-1} = I$, the NxN unit matrix by definition of the inverse, this is consistent with the row of B = ($a1^*$, $a2^*$, $a3^*$ .... $a(n)^*$times the column of B being equal to $|a1|^2 + |a2|^2 \ldots + |a(n)|^2 = 1$, giving a "1" on the diagonal, but other rows of B times the same column of the inverse must gives zeros, as the off-diagonal elements of the unit matrix I are zero. All other rows of B must therefore be orthogonal to the column of B^{-1} formed by the a(i) values. Denoting any other row of B by (r1, r2....r(n)) we must therefore have

$$r1.a1 + r2.a2 + r3.a3 \ldots \ldots + r(n).a(n) = 0$$

It can also arbitrarily be required that $r1^2 + r2^2 + r(n)^2 = 1$.

[0058] Such a matrix constructed with one row equal to a given vector, all other rows being orthogonal to it and the sum of the moduli squared of any row being equal to unity is called an orthonormal matrix, and may be constructed by the known process of Gram-Schmidt orthonormalization. There are some degrees of freedom in assigning values to the other rows, and if desired as indicated above, this may be done in such a way as to maximize the total number of zeros in the matrix.

[0059] Therefore, it has been shown that the beamforming matrix can be constructed by setting one row equal to the conjugates of the received signal gains and phases at the N antenna element columns, the other N-1 rows being constructed by Gram-Schmidt orthonormalization.

[0060] Another formulation of the beamformer may be made using Butler matrices or their numerical counterparts, discrete Fourier transforms. A set of signals from the N antenna element columns 20 disposed around the cylinder 21 in a regular fashion is connected to a Butler matrix 80. The Butler matrix 80 produces N transformed signal outputs which are related to the N input signals by an NxN discrete Fourier transform matrix which has the Orthonormal property. When a signal impinges on the array from a direction THETA which is slowly changing, the signal pattern received at the elements slowly moves around the array, becoming identical with the pattern a value 2Pi/N of THETA earlier merely shifted by one element. The Butler-matrix transformed values become equal in amplitude to the values at an earlier value of THETA, THETA-2Pi/N likewise, while the phase shifts of the transformed values are changed by multiples of

2Pi/N. In fact, the amplitudes of the transformed values are very nearly the same for all values of THETA, while only the phase changes by multiples of THETA. Therefore, the desired weighting of the element signals can, to a sufficient accuracy, be provided by means of a constant amplitude shaping performed by applying different gains or attenuation factors c1,c2....c(n) in an amplitude shaping unit 81, which also may insert fixed phase changes if necessary for transformed components 1 to N, while a phasing unit 82 changes the phase of each transformed and amplitude-shaped value by multiples of the direction of arrival angle THETA.

[0061] Finally, if the phasing unit 82 is chosen to provide the phases necessary for N beams simultaneously that are spaced by multiples of 2Pi/N, then the phasing unit 82 is an inverse Butler matrix (or inverse Fourier transform in the numerical domain).

[0062] In Figure 5 it is shown that the input buffers have been transferred to the outputs of the Butler Matrix unit 80 and the amplitude shaper 81. This is possible because functions performed by the Butler Matrix unit 80 and the amplitude shaper 81 are neither direction-of-arrival nor time-of-arrival dependent and may be performed on a sample-by-sample basis, and the results held in the buffers 72. The barrel shifters (not shown) as described above then select 128 of the 128+L locations of each of the N buffers to form the N inputs to 128 phasing units 82 that complete the beamforming for a ray with a particular time-of-arrival and direction-of-arrival. After signal detection and subtraction, the residual signal need only be inverse transformed as far as input buffers 72 and need not be transformed back through the amplitude shaping unit 81 nor through the Butler matrix 80.

[0063] The advantage of performing the fixed transformation of the Butler matrix 80 and the amplitude shaping 81 prior to entering the input buffers illustrated in Figure 4 is that the beamforming units 70 become simply phasing units 82 that only change the phases of the signals prior to combining them and do not weight the amplitudes. The phasing units 82 may moreover be efficiently implemented using an Fast Fourier Transform (FFT). The FFT produces beams with spacing 2Pi/N from a starting angle THETA that is implemented by applying a fixed phase slope to the input values given by the factors

- 1, EXP (THETA), EXP (2·THETA), EXP (3·THETA) .....

where THETA is between 0 and Pi/N, or between -Pi/N and +Pi/N. THETA in this case represents a fine direction-of-arrival resolution to accuracies of less than 2Pi/N while the FFT resolves the beams in steps of 2Pi/N.

[0064] Figure 5 when combined with Figure 4 exhibits a cascade of FFT processors operating in one dimension of a 2-dimensional array of numbers with FWT processors operating in the second dimension. FWTs and FFTs are both in the family of Walsh-Fourier transforms, that differ only in their application of steps known as "Twiddling". A Fast Walsh-Fourier transform comprises stages for combing pairs of values called "Butterflies" that compute a sum and a difference interspersed with stages for rotating the phases of the complex sum and differences by fixed amounts, called "Twiddling". A pure Fourier transform has twiddling between every two successive Butterfly stages, while a pure Fast Walsh Transform has no Twiddling stages. A hybrid Walsh-Fourier transform has some Twiddling stages; a two dimensional Fourier Transform is one example and omits one twiddling stage. A Fourier transform on a 3-dimensional array of numbers is structured the same as a 1D Fourier transform operating on all the numbers arranged in one big vector, but omits two twiddling stages, and so on, that is M-1 twiddling stages are omitted in performing an M-dimensional Fourier Transform. For the phasing units 82 of Figure 5 and the FWT processors 71 of Figure 4, the combined transform may be performed very efficiently by using one large 1-dimensional transform of all 128 x N values arranged in a single vector, just omitting 6 twiddling stages corresponding to the 128-point FWT portions, which are equivalent to a seven-dimensional Fourier transform having two data values in each dimension, and omitting a further stage of twiddling corresponding to the 2-dimensional cascade of the FFT with the FWT portion.

[0065] An example will make this clearer: Fast Walsh-Fourier transforms may be constructed most efficiently when the total data array comprises a number of values equal to a power of two. Thus, if the number of beams N is chosen to be a power of two, for example 32, since the FWT portion of size 128 is already a power of two, then the total number of data values will be 32 x 128 or 4096, which is 2^{12}.

[0066] A 2^{12} FFT would normally comprise 12 Butterfly stages with 11 Twiddling stages between them. In the present application however, the required transform is an 8-dimensional transform of an 8-dimensional array of values of size

$$32x2x2x2x2x2x2x2 = 4096 \text{ values in total.}$$

[0067] Accordingly, the number of twiddling stages is reduced by 8-1 = 7, leaving only 4 out of the 11 which a 4096-point FWT can accommodate. The four remaining correspond to those lying between the first 5 Butterfly stages of the 32-point FFT portions.

[0068] Thus it has been shown above that the cascade of FFT beamformers 82 in one data plane with FWT decoders 71 in a second data plane may be performed using a generalised single-dimensional Fast Walsh-Fourier transform programmed to delete appropriate stages of twiddling. If such a device is constructed sufficiently, efficiently and economically, it may become uninteresting to omit computation of unused FWTs or beams and simpler to compute the

whole set for every ray.

[0069] A further variation is to note that the exact beam direction for a ray, formed by customizing the value of THETA in Figure 5 for each ray independently, is only of relevance in obtaining accurate signal subtraction. Accurate signal detection in the detection phase can be performed by computing only sets of beams using THETA-0, in which case a particular signal happening to have a direction-of-arrival midway between two beams will show up in those two adjacent beams, appearing as two rays. As long as the channel trackers 73 supply appropriate coefficients for the two adjacent beams however, correct detection will result. The subtraction phase however preferably uses the correct value of THETA to cause the signal to appear in only one of the computed beams, from which it is nulled out. The value of THETA required may be determined by the channel tracker from the RAKE coefficients for the two adjacent beams used for detection.

[0070] Still other variations comprise, instead of setting a transform component to zero, after updating the channel tracker for the just-detected symbol value to predict the next value, the updated predicted value is subtracted from the transform component before performing the inverse transform.

[0071] It is beyond the scope of this application to provide a detailed analysis of all the pro's and con's for one variation or another, the selection of which depends on the exact parameters of a particular implementation, e.g. number of antenna columns, size of Walsh-Hadamard codewords, signal bandwidth, traffic capacity and whether the implementation of computations is by means of programmable signal processors, hardwired logic or Applications-Specific Integrated Circuits (ASIC) the capabilities of which are ever-increasing due to rapid advance in silicon integration technology.

[0072] All such variations incorporating the inventive principle of subtractive demodulation of signals in both a signal (or code) space and a spatial dimension (or antenna beam space) that may be made by a person skilled in the art are considered to lie within the scope of the following claims.

Claims

1. A communications system comprising a plurality of mobile stations and an improved base station for receiving signals from said mobile stations and decoding information-bearing signals transmitted therefrom, the base station comprising:

   a) antenna means (20-22) comprising antenna elements (22) disposed around a support structure (21) for receiving signals transmitted from said plurality of mobile stations and generating output signals (23) from each antenna element (22);

   b) conversion means (30, 31) for amplifying (311, 315), filtering (310, 312, 314), and converting (316) signals from each of said antenna elements (22) into a corresponding number of converted signals (36), for processing;

   c) storage means for temporarily storing a number of samples of said converted signals (36) at successive instants in time; and

   d) processing means (70, 71) for iteratively processing and reprocessing said stored samples successively to decode said information from each of said mobile stations in turn, wherein the processing provided by said processing means identifies from said stored samples an information symbol transmitted by one of said mobile stations thereby decoding said information-bearing signal and subtracts values dependent on said identified - information symbol from said stored samples of all antenna element signals thereby reducing interference between the just-decoded signal and the signal to be decoded at a subsequent iteration.

2. The communications system of claim 1, wherein at least some of said mobile stations transmit said information using the same radio frequency channel at the same time.

3. The communications system of claim 1, wherein at least some of said mobile stations transmit Code Division Multiple Access signals.

4. A communications system according to claim 1, wherein said processing means further comprises:

   means for combining corresponding ones of said stored samples converted from respective antenna elements to enhance signals received from a particular direction, wherein a particular one of said mobile stations lies.

5. The communications system of claim 1, wherein said successively decoded signals are selected in descending order of received signal strength.

6. The communications system of claim 4, wherein said means for combining computes a weighted sum of the combined values using as the weights a set of complex beamforming coefficients.

7. The communications system of claim 6, wherein said beamforming coefficients are adapted at each iteration to enhance the signal being decoded at that iteration.

8. The communications system of claim 1, wherein said processing means comprises:

   beamforming means for combining groups of said stored samples comprising a signal sample converted by said conversion means from each antenna at the same instant in time to produce beam samples for signals received from a plurality of directions of arrival at a corresponding instant in time.

9. The communications system of claim 8, further comprising: CDMA despreading means for processing said beam samples received at successive instants in time from the same one of said plurality of directions of arrival in order to identify said identified symbol transmitted from one of said mobile station and received at said improved base station from said direction of arrival.

10. The communications system of claim 9, wherein said CDMA despreading means comprises computing a Walsh-Hadamard transform to obtain a number of Walsh spectrum components each corresponding to one of an allowed alphabet of information symbols.

11. The communications system of claim 10, wherein said identified symbol is identified by determining the largest of said Walsh spectrum components and thus the corresponding symbol from said allowed alphabet of symbols.

12. The communications system of claim 11, wherein said largest Welsh spectrum component is set to zero after being determined to be the largest.

13. The communications system of claim 12, wherein said Walsh spectrum after having said largest component set to zero is inverse Walsh-Hadamard transformed to obtain modified beam samples.

14. The communications system of claim 13, wherein said modified beam samples are combined using an inverse beamforming means to obtain modified stored samples which replace the original ones of said stored samples prior to performing a subsequent iteration to decode a symbol from a different mobile transmitter.

15. A communications system according to claim 1, wherein said improved base station is adapted for receiving said signals transmitted from said mobile stations each with the aid of an assigned access code (14), wherein said processing means is adapted for arranging said samples received sequentially in time from said antenna elements in a two-dimensional space/time array, one dimension thereof corresponding to the different antenna elements and the other dimension corresponding to time of reception, and for unscrambling the stored numerical samples using one of said access codes assigned to a first one of said mobile stations, and comprises: two-dimensional numerical transform means (71) for processing said unscrambled stored samples to produce a two-dimensional space/code array of transformed samples, the space dimension of said two-dimensional space/code array corresponding to different possible directions of arrival of signals at said base station transmitted by said first mobile station and the code dimension of said two-dimensional array corresponding to the information symbols in an allowed alphabet of symbols, wherein the transformed samples for a fixed arrival direction value of the space dimension indicate the correlations with the different information symbols along the code dimension.

16. The communications system of claim 1, wherein said access code used is chosen to be that assigned to the mobile station that is received with greatest signal strength at said base station.

17. The communications system of claim 15, **characterized** by decoding means for decoding of one of said information symbols, comprising a determining means for determining the largest of said transformed samples and thereby identifying a symbol belonging to said allowed alphabet of symbols and also a direction of arrival of the signal, wherein said information symbol was encoded.

18. The communications system of claim 15, **characterized by** decoding means for said decoding of one of said information symbols, comprising a combining means for combining said transformed samples that lie adjacent along the direction-of-arrival dimension using a set of combining coefficients to produce a combined value for each position in the other dimension of said two dimensional array of transformed samples.

19. The communications system of claim 18, **characterized by** a determining means for determining the largest of said combined values and thereby identifying said decoded information symbol.

20. The communications system of claim 17, wherein the largest of said transformed samples is et to zero after identifying said symbol.

21. The communications system of claim 20, further comprising: inverse two-dimensional transform means (71) for transforming said transformed samples having one sample set to zero to obtain modified stored samples stored in said storage means (70).

22. The communications system of claim 21, **characterized by** means (71) for processing said modified stored samples using said two-dimensional transform means with the access code assigned to a second mobile station and thereby identifying a symbol transmitted by said second mobile station.

23. The communications system of claim 22, wherein after identifying the symbol transmitted by said second mobile station, a corresponding transform component is set to zero and then performing said inverse two-dimensional transform is performed to produce further modified stored samples.

24. The communications system according to claim 23, wherein said further modified samples are iteratively processed using successively selected access codes to identify successively symbols transmitted from mobile stations assigned said access codes and after identifying each symbol to further modify said stored samples by setting to zero a transformed component and performing an inverse transform.

25. The communications system of claim 24, wherein said successively selected access codes are assigned to mobile stations received at said base station in successively descending signal strength order.

26. A communications system according to claim 15, **characterized in that**
said two-dimensional numerical transform means (71) performs said processing of said stored samples using a prescribed time-shift numerical transform means (71) are provided for between the samples correlated and said information symbols; said two-dimensional repeating said two-dimensional transform for a plurality of said time-shifts corresponding to delayed reception of signals from said first mobile station corresponding to delayed echoes of said signals caused by signals reflection from objects in the propagation path.

27. The communications system of claim 26, **characterized by** means (73) to predict the direction of arrival and corresponding time-of-arrival of each of said echoes of significant strength and to adapt thereto said possible different directions of arrival assumed by said two-dimensional numerical transform means and said prescribed time-shifts used for correlation.

28. The communications system of claim 27, **characterized by** combining means (74) for combining using a set of weighting coefficients transformed components corresponding to said predicted directions and times of arrival to obtain a set of combined values corresponding to correlation with each symbol in said allowed alphabet of symbols.

29. The communications system of claim 28, **characterized by** one of said combined values that has the largest magnitude is determined and thereby identifies a symbol transmitted by said first station.

30. The communications system of claim 29, **characterized by** means (74) for setting to zero two-dimensionally transformed components corresponding to said identified symbol and corresponding to said predicted directions and times of arrival and inverse transforming said transformed components after setting said symbol, time and direction-corresponding component to zero to obtain modified stored sample values.

31. The communications system off claim 30, **characterized by** means (74) for iteratively reprocessing said modified stored samples using successively selected access codes to identify in turn a symbol transmitted by the mobile station assigned the selected access code and after each iteration generating further modified stored samples for

processing in the next iteration.

32. The communications system of claim 31, **characterized in that** said access codes are selected in descending order of received signal strength of the corresponding mobile station to which the access code is assigned.

33. A method for receiving signals transmitted from a plurality of mobile stations, in a communication system comprising said mobile stations and an improved base station, each signal received with the aid of a respectively assigned access code (14) and said access code used for decoding information symbols belonging to an allowed alphabet of symbols encoded in said transmissions, comprising the steps of:

   a) receiving signals transmitted from said plurality of mobile stations at antenna means (20-22) with antenna elements (22) disposed around a support structure (21) and generating output signals (23) from each antenna element (22);
   b) amplifying (311, 315), filtering (310, 312, 314) and converting (316) signals from each of said antenna elements (22) into a corresponding number of converted signals (36) for processing;
   c) temporarily storing a number of samples (36) of said signals converted from each of said antenna elements (22) at successive instants in time (t1 ... t128);
   d) processing means (70, 71) for iteratively processing and reprocessing said stored samples successively to decode said information from each of said mobile stations in turn, wherein the processing provided by said processing means identifies from said stored samples an information symbol transmitted by one of said mobile stations thereby decoding said information-bearing signal and subtracts values dependent on said identified information symbol from said stored samples of all antenna element signals thereby reducing interference between the just-decoded signal and the signal to be decoded at a subsequent iteration.

34. A method according to claim 33, wherein said improved base station is adapted for receiving said signals transmitted from said mobile stations each with the aid of an assigned access code (14), further comprising the steps of arranging (71) said samples received sequentially in time from said antenna elements in a two-dimensional space/time array, one dimension thereof corresponding to the different antenna elements and the other dimension corresponding to time of reception, unscrambling (71) the stored numerical samples using one of said access codes assigned to a first one of said mobile stations, and processing (71) said unscrambled stored samples to produce a two-dimensional space/code array of transformed samples, the space dimension of said two-dimensional space/code array corresponding to different possible directions of arrival of signals at said base station transmitted by said first mobile station and the code dimension of said two-dimensional array corresponding to the information symbols in an allowed alphabet of symbols, wherein the transformed samples for a fixed arrival direction value of the space dimension indicate the correlations with the different information symbols along the code dimension.

35. A method according to claim 34, **characterized in that** said processing (71) is performed by using a prescribed time-shift between the samples correlated and said information symbols; and
repeating said two-dimensional transform for a plurality of said time-shifts corresponding to delayed reception of signals from said first mobile station corresponding to delayed echoes of said signals caused by signals reflection from objects in the propagation path.

36. The method according to claim 35, further comprising the steps of: predicting (73) the direction of arrival and corresponding time-of-arrival of each of said echoes of significant strength and to adapt thereto said possible different directions of arrival assumed by said two-dimensional numerical transform means and said prescribed time-shifts used for correlation.

37. The method according to claim 36, further comprising the steps of: combining (74) using a set of weighting coefficients transformed components corresponding to said predicted directions and times of arrival to obtain a set of combined values corresponding to correlation with each symbol in said allowed alphabet of symbols.

38. The method according to claim 37, wherein one of said combined values that has the largest magnitude is determined and thereby identifies a symbol transmitted by said first station.

39. The method according to claim 38, further comprising the steps of: setting to zero two-dimensionally transformed components corresponding to said identified symbol and corresponding to said predicted directions and times of arrival and inverse transforming said transformed components after setting said symbol, time and direction-corre-

sponding component to zero to obtain modified stored sample values.

40. The method according to claim 39, further comprising the steps of: iteratively reprocessing said modified stored samples using successively selected access codes to identify in turn a symbol transmitted by the mobile station assigned the selected access code and after each iteration generating further modified stored samples for processing in the next iteration.

41. The method according to claim 40, wherein said access codes are selected in descending order of received signal strength of the corresponding mobile station to which the access code is assigned.

Patentansprüche

1. Kommunikationssystem, umfassend eine Vielzahl von Mobilstationen und eine verbesserte Basisstation zum Empfangen von Signalen von den Mobilstationen und Dekodieren von Informations-tragenden Signalen, die davon gesendet werden, wobei die Basisstation umfasst:

   a) eine Antenneneinrichtung (20-22), die Antennenelemente (22) umfasst, die um einen Halterungsaufbau (21) herum angeordnet sind, zum Empfangen von Signalen, die von der Vielzahl von Mobilstationen gesendet werden, und Erzeugen von Ausgangssignalen (23) von jedem Antennenelement (22);

   b) eine Umwandlungseinrichtung (30, 31) zum Verstärken (311, 315), Filtern (310, 312, 314) und Umwandeln (316) von Signalen von jedem der Antennenelemente (22) in eine entsprechende Anzahl von umgewandelten Signalen (36), für eine Verarbeitung;

   c) eine Speichereinrichtung zum vorübergehenden Speichern einer Anzahl von Abtastwerten der umgewandelten Signale (36) bei sukzessiven Zeitaugenblicken; und

   d) eine Verarbeitungseinrichtung (70, 71) zum iterativen Verarbeiten und Neuverarbeiten der gespeicherten Abtastwerte sukzessive, um wiederum die Information von jeder der Mobilstationen zu dekodieren, wobei die Verarbeitung, die von der Verarbeitungseinrichtung bereitgestellt wird, aus den gespeicherten Abtastwerten ein Informationssymbol identifiziert, das von einer der Mobilstationen gesendet wird, wodurch das Informations-tragende Signal dekodiert wird, und Werte in Abhängigkeit von dem identifizierten Informationssymbol aus den gespeicherten Abtastwerten von sämtlichen Antennenelementsignalen subtrahiert, wodurch eine Störung zwischen dem eben dekodierten Signal und dem bei einer nachfolgenden Iteration zu dekodierenden Signal verringert wird.

2. Kommunikationssystem nach Anspruch 1, wobei wenigstens einige der Mobilstationen die Information unter Verwendung des gleichen Funkfrequenzkanals gleichzeitig senden.

3. Kommunikationssystem nach Anspruch 1, wobei wenigstens einige der Mobilstationen Codevielfachzugriff-Signale senden.

4. Kommunikationssystem nach Anspruch 1, wobei die Verarbeitungseinrichtung ferner umfasst:

   eine Einrichtung zum Kombinieren von entsprechenden der gespeicherten Abtastwerte, die von jeweiligen Antennenelementen umgewandelt sind, um Signale zu verbessern, die aus einer bestimmten Richtung empfangen werden, in der eine bestimmte der Mobilstationen liegt.

5. Kommunikationssystem nach Anspruch 1, wobei die sukzessiv dekodierten Signale in einer abfallenden Reihenfolge der empfangenen Signalstärke gewählt werden.

6. Kommunikationssystem nach Anspruch 4, wobei die Einrichtung zum Kombinieren eine gewichtete Summe der kombinierten Werte unter Verwendung eines Satzes von komplexen strahlbildenden Koeffizienten als die Gewichte berechnet.

7. Kommunikationssystem nach Anspruch 6, wobei die strahlbildenden Koeffizienten dafür ausgelegt sind, um bei jeder Iteration das Signal zu verbessern, welches bei dieser Iteration dekodiert wird.

8. Kommunikationssystem nach Anspruch 1, wobei die Verarbeitungseinrichtung umfasst:

eine Strahlbildungseinrichtung zum Kombinieren von Gruppen der gespeicherten Abtastwerte, umfassend einen Signalabtastwert, der von der Umwandlungseinrichtung von jeder Antenne zu dem gleichen Zeitaugenblick umgewandelt wird, um Strahlabtastwerte für Signale zu erzeugen, die von einer Vielzahl von Ankunftsrichtungen zu einem entsprechenden Zeitaugenblick empfangen werden.

9. Kommunikationssystem nach Anspruch 8, ferner umfassend:

eine CDMA Entspreizungseinrichtung zum Verarbeiten der Strahlabtastwerte, die zu sukzessiven Zeitaugenblicken von der gleichen der Vielzahl von Ankunftsrichtungen empfangen werden, um das identifizierte Symbol zu identifizieren, das von einer der Mobilstationen gesendet und an der verbesserten Basisstation aus der Ankunftsrichtung empfangen wird.

10. Kommunikationssystem nach Anspruch 9, wobei die CDMA Entspreizungseinrichtung die Berechnung einer Walsh-Hadamard Transformation umfasst, um eine Anzahl von Walsh Spektrumkomponenten zu ermitteln, die jeweils einem eines zugelassenen Alphabets von Informationssymbolen entsprechen.

11. Kommunikationssystem nach Anspruch 10, wobei das identifizierte Symbol durch Bestimmen der größten der Walsh Spektrumkomponenten und somit des entsprechenden Symbols aus dem zugelassenen Alphabet von Symbolen identifiziert wird.

12. Kommunikationssystem nach Anspruch 11, wobei die größte Walsh Spektrumkomponente auf Null gesetzt wird, nachdem bestimmt wird, dass sie die größte ist.

13. Kommunikationssystem nach Anspruch 12, wobei das Walsh Spektrum, nachdem die größte Komponente auf Null gesetzt worden ist, eine inverse Walsh-Hadamard Transformation durchläuft, um modifizierte Strahlabtastwerte zu ermitteln.

14. Kommunikationssystem nach Anspruch 13, wobei die modifizierten Strahlabtastwerte unter Verwendung einer inversen Strahlformungseinrichtung kombiniert werden, um modifizierte gespeicherte Abtastwerte zu ermitteln, die die ursprünglichen der gespeicherten Abtastwerte ersetzen, vor einer Ausführung einer nachfolgenden Iteration, um ein Symbol von einem anderen mobilen Sender zu dekodieren.

15. Kommunikationssystem nach Anspruch 1, wobei die verbesserte Basisstation dafür ausgelegt ist, um die von den Mobilstationen gesendeten Signale jeweils mit Hilfe eines zugewiesenen Zugriffscodes (14) zu empfangen, wobei die Verarbeitungseinrichtung dafür ausgelegt ist, um die sequentiell zeitlich von den Antennenelementen empfangenen Abtastwerte in einem zweidimensionalen Raum/Zeit-Feld anzuordnen, wobei eine Dimension davon den verschiedenen Antennenelementen entspricht und die andere Dimension einer Empfangszeit entspricht, und zum Entscrambeln der gespeicherten numerischen Abtastwerte unter Verwendung von einem der Zugriffscodes, der einer ersten der Mobilstationen zugewiesen ist, und umfasst: eine zweidimensionale numerische Transformationseinrichtung (71) zum Verarbeiten der entscrambelten gespeicherten Abtastwerte, um ein zweidimensionales Raum/Code-Feld von transformierten Abtastwerten zu erzeugen, wobei die Raumdimension des zweidimensionalen Raum/Code-Felds verschiedenen möglichen Ankunftsrichtungen von Signalen an der Basisstation, die von der Mobilstation gesendet werden, entspricht und die Code-Dimension des zweidimensionalen Felds den Informationssymbolen in einem zugelassenen Alphabet von Symbolen entspricht, wobei die transformierten Abtastwerte für einen festen Ankunftsrichtungswert der Raumdimension die Korrelationen mit den verschiedenen Informationssymbolen entlang der Code-Dimension anzeigen.

16. Kommunikationssystem nach Anspruch 1, wobei der verwendete Zugriffscode gewählt wird, um derjenige zu sein, der der Mobilstation zugewiesen ist, die mit der größten Signalstärke an der Basisstation empfangen wird.

17. Kommunikationssystem nach Anspruch 15, **gekennzeichnet durch** eine Dekodierungseinrichtung zum Dekodieren von einem der Informationssymbole, umfassend eine Bestimmungseinrichtung zum Bestimmen des größten der transformierten Abtastwerte und dadurch zum Identifizieren eines Symbols, das zu dem zugelassenen Alphabet von Symbolen und auch einer Ankunftsrichtung des Signals gehört, aus der das Informationssymbol kodiert wurde.

18. Kommunikationssystem nach Anspruch 15, **gekennzeichnet durch** eine Dekodierungseinrichtung für die Dekodierung von einem der Informationssymbole, umfassend eine Kombiniereinrichtung zum Kombinieren der transformierten Abtastwerte, die benachbart entlang der Ankunftsrichtungsdimension liegen, unter Verwendung eines Satzes von Kombinierkoeffizienten, um einen kombinierten Wert für jede Position in der anderen Dimension des zweidimensionalen Felds von transformierten Abtastwerten zu erzeugen.

19. Kommunikationssystem nach Anspruch 18, **gekennzeichnet durch** eine Bestimmungseinrichtung zum Bestimmen des größten der kombinierten Werte und **dadurch** zum Identifizieren des dekodierten Informationssymbols.

20. Kommunikationssystem nach Anspruch 17, wobei der größte der transformierten Abtastwerte auf Null nach einem Identifizieren des Symbols gesetzt wird.

21. Kommunikationssystem nach Anspruch 20, ferner umfassend eine inverse zweidimensionale Transformationseinrichtung (71) zum Transformieren der transformierten Abtastwerte, bei denen ein Abtastwert auf Null gesetzt ist, um modifizierte gespeicherte Abtastwerte zu ermitteln, die in der Speichereinrichtung (70) gespeichert werden.

22. Kommunikationssystem nach Anspruch 21, **gekennzeichnet durch** eine Einrichtung (71) zum Verarbeiten der modifizierten gespeicherte Abtastwerte unter Verwendung der zweidimensionalen Transformationseinrichtung mit dem einer zweiten Mobilstation zugewiesenen Zugriffscode und **dadurch** zum Identifizieren eines Symbols, das von der zweiten Mobilstation gesendet wird.

23. Kommunikationssystem nach Anspruch 22, wobei nach einem Identifizieren des Symbols, das von der zweiten Mobilstation gesendet wird, eine entsprechende Transformationskomponente auf Null gesetzt wird und dann eine Ausführung der inversen zweidimensionalen Transformation ausgeführt wird, um weitere modifizierte gespeicherte Abtastwerte zu erzeugen.

24. Kommunikationssystem nach Anspruch 23, wobei die weiter modifizierten Abtastwerte iterativ unter Verwendung von sukzessive gewählten Zuggriffscodes verarbeitet werden, um sukzessive Symbole, die von Mobilstationen gesendet werden, denen die Zugriffscodes zugewiesen sind, zu identifizieren und um nach einem Identifizieren jedes Symbols die gespeicherten Abtastwerte weiter zu modifizieren, indem eine Transformationskomponente auf Null gesetzt wird und eine inverse Transformation ausgeführt wird.

25. Kommunikationssystem nach Anspruch 24, wobei die sukzessive gewählten Zuggriffscodes Mobilstationen, die an der Basisstation empfangen werden, in eine sukzessive abnehmenden Signalstärkereihenfolge zugewiesen werden.

26. Kommunikationssystem nach Anspruch 15,
dadurch gekennzeichnet, dass
die zweidimensionale numerische Transformationseinrichtung (71) die Verarbeitung der gespeicherten Abtastwerte unter Verwendung einer vorgeschriebenen numerischen Zeitverschiebungs-Transformationseinrichtung (71) zwischen den korrelierten Abtastwerten und den Informationssymbolen ausführt, wobei das zweidimensionale Widerholen der zweidimensionalen Transformation für eine Vielzahl der Zeitverschiebungen einem verzögerten Empfang von Signalen von der ersten Mobilstation entsprechend zu verzögerten Echos der Signale, verursacht durch Signalreflexionen von Objekten in dem Ausbreitungspfad, entspricht.

27. Kommunikationssystem nach Anspruch 26, **gekennzeichnet durch** eine Einrichtung (73) zur Vorhersage der Ankunftsrichtung und einer entsprechenden Ankunftszeit von jedem der Echos einer signifikanten Stärke und zum Anpassen der möglichen verschiedenen Ankunftsrichtungen, die von der zweidimensionalen numerischen Transformationseinrichtung angenommen werden, und der vorgeschriebenen Zeitverschiebungen, die für eine Korrelation verwendet werden, darauf.

28. Kommunikationssystem nach Anspruch 27, **gekennzeichnet durch** eine Kombiniereinrichtung (74) zum Kombinieren unter Verwendung eines Satzes von Gewichtungskoeffizienten-transformierten Komponenten entsprechend zu den vorgegebenen Ankunfts-Richtungen und -zeiten, um einen Satz von kombinierten Werten entsprechend zu einer Korrelation mit jedem Symbol in dem zugelassenen Alphabet von Symbolen zu ermitteln.

29. Kommunikationssystem nach Anspruch 28,
dadurch gekennzeichnet, dass

einer der kombinierten Werte, der die größte Größe aufweist, bestimmt wird und dadurch ein Symbol identifiziert, das von der ersten Station gesendet wird.

30. Kommunikationssystem nach Anspruch 29, **gekennzeichnet durch** eine Einrichtung (74) zum Einstellen auf Null von zweidimensionalen Transformationskomponenten, die dem identifizierten Symbol entsprechen und den vorgegebenen Ankunfts-Richtungen und -zeiten entsprechen, und inversen Transformieren der transformierten Komponenten nach Setzen des Symbols, der Zeit und der Richtungs-entsprechenden Komponente auf Null, um modifizierte gespeicherte Abtastwerte zu ermitteln.

31. Kommunikationssystem nach Anspruch 30, **gekennzeichnet durch** eine Einrichtung (84) zum iterativen Neuverarbeiten der modifizierten gespeicherten Abtastwerte unter Verwendung von sukzessive gewählten Zugriffscodes, um wiederum ein Symbol zu identifizieren, das von der Mobilstation gesendet wird, der der gewählte Zugriffscode zugewiesen ist, und nach jeder Iteration zum Erzeugen von weiter modifizierten gespeicherten Abtastwerten für eine Verarbeitung in der nächsten Iteration.

32. Kommunikationssystem nach Anspruch 31,
dadurch gekennzeichnet, dass die Zugriffscodes in einer abfallende Reihenfolge der empfangenen Signalstärke der entsprechende Mobilstation, der der Zugriffscode zugewiesen ist, gewählt werden.

33. Verfahren zum Empfangen von Signalen, die von einer Vielzahl von Mobilstationen gesendet werden, in einem Kommunikationssystem, welches die Mobilstationen und eine verbesserte Basisstation umfasst, wobei jedes Signal mit Hilfe eines jeweils zugewiesenen Zugriffscodes (14) empfangen wird und der Zugriffscodes zum Dekodieren von Informationssymbolen verwendet wird, die zu einem zugelassenen Alphabet von Symbolen gehören, die in die Aussendungen kodiert sind, umfassend die folgenden Schritte:

a) Empfangen von Signalen die von der Vielzahl von Mobilstationen gesendet werden, an einer Antenneneinrichtung (20-22) mit Antennenelementen (22), die um einen Halterungsaufbau (21) herum angeordnet sind, und zum Erzeugen von Ausgangssignalen (23) für jedes Antennenelement (22);

b) Verstärken (311, 315(, Filtern (310, 312, 314), und Umwandeln (316) von Signalen von jedem der Antennenelemente (22) in eine entsprechende Anzahl von umgewandelten Signalen (36) für eine Verarbeitung;

c) vorübergehendes Speichern einer Anzahl von Abtastwerten (36) der Signale, die von jedem der Antennenelemente (22) bei sukzessiven Zeitaugenblicken (t1 .... t128) umgewandelt werden;

d) eine Verarbeitungseinrichtung (70, 71) zum iterativen Verarbeiten und Neuverarbeiten der gespeicherten Abtastwerte sukzessive, um wiederum die Information von jeder der Mobilstationen zu dekodieren, wobei die Verarbeitung, die von der Verarbeitungseinrichtung bereitgestellt wird, aus den gespeicherten Abtastwerten ein Informationssymbol identifiziert, das von einer der Mobilstationen gesendet wird, wodurch das Informations-tragende Signal dekodiert wird und Werte in Abhängigkeit von dem identifizierten Informationssymbol von den gespeicherten Abtastwerten von sämtlichen Antennenelementsignalen subtrahiert, wodurch eine Störung zwischen dem eben dekodierten Signal und dem bei einer nachfolgenden Iteration zu dekodierendem Signal verringert wird.

34. Verfahren nach Anspruch 33, wobei die verbesserte Basisstation ausgelegt ist zum Empfangen der Signale, die von den Mobilstationen gesendet werden, jeweils mit Hilfe eines zugewiesenen Zugriffscodes (14), ferner umfassend die Schritte zum Anordnen (71) der Abtastwerte, die zeitlich sequentiell von den Antennenelementen empfangen werden, in einem zweidimensionalen Raum/Zeit-Feld, wobei eine Dimension davon den verschiedenen Antennenelementen entspricht und wobei die andere Dimension der Empfangszeit entspricht, Entscrambeln (71) der gespeicherten numerischen Abtastwerte unter Verwendung von einem der Zugriffscodes, der eine ersten der Mobilstationen zugewiesen ist, und Verarbeiten (71) der entscrambelten gespeicherten Abtastwerte zum Erzeugen eines zweidimensionalen Raum/Code-Felds von transformierten Abtastwerten, wobei die Raumdimensionen des zweidimensionalen Raum/Code-Felds verschiedenen möglichen Ankunftsrichtungen von Signalen an der Basisstation, die von der Mobilstation gesendet werden, entspricht und die Code-Dimension des zweidimensionalen Felds den Informationssymbolen in einem zugelassen Alphabet von Symbolen entspricht, wobei die transformierten Abtastwerte für einen festen Ankunftsrichtungswert der Raumdimension die Korrelationen mit den verschiedenen Informationssymbolen entlang der Code-Dimension anzeigen.

35. Verfahren nach Anspruch 34,
dadurch gekennzeichnet, dass
die Verarbeitung (71) durch Verwenden einer vorgeschriebenen Zeitverschiebung zwischen den korrellerten Abtastwerten und den Informationssymbolen ausgeführt wird; und
Wiederholen der zweidimensionalen Transformation für eine Vielzahl der Zeitverschiebungen entsprechend zu einem verzögerten Empfang von Signalen von der ersten Mobilstation entsprechend zu verzögerten Echos der Signale, die von einer Signalreflexion von Objekten in dem Ausbreitungspfad verursacht werden.

36. Verfahren nach Anspruch 35, umfassend die folgenden Schritte: Vorhersagen (73) der Ankunftsrichtung und einer entsprechenden Ankunftszeit von jedem der Echos einer signifikanten Stärke und um darauf die möglichen verschiedenen Ankunftsrichtungen, die von der zweidimensionalen numerischen Transformationseinrichtung angenommen werden, und die vorgeschriebenen Zeitverschiebungen, die für eine Korrelation verwendet werden, anzupassen.

37. Verfahren nach Anspruch 36, ferner umfassend die folgenden Schritte: Kombinieren (74) unter Verwendung eines Satzes von Gewichtungskoeffizienten-transformierten Komponenten entsprechend zu den vorgeschriebenen Richtungen und Ankunftszeiten, um einen Satz von kombinierten Werten entsprechend zu einer Korrelation mit jedem Symbol in dem zugelassenen Alphabet von Symbolen zu ermitteln.

38. Verfahren nach Anspruch 37, wobei einer der kombinierten Werte, der die größte Größe aufweise, bestimmt wird und dadurch ein Symbol identifiziert, das von der ersten Station gesendet wird.

39. Verfahren nach Anspruch 38, ferner umfassend die folgenden Schritte: Einstellen von zweidimensional transformierten Komponenten entsprechend zu dem identifizierten Symbol und entsprechend zu vorgeschriebenen Ankunfts-Richtungen und -zeiten auf Null und inverses Transformieren der transformierten Komponenten nach Setzen des Symbols, der Zeit und Richtungs-entsprechenden Komponente auf Null, um modifizierte gespeicherte Abtastwerte zu ermitteln.

40. Verfahren nach Anspruch 39, ferner umfassend die folgenden Schritte: iteratives Neuverarbeiten der modifizierten gespeicherten Abtastwerte unter Verwendung von sukzessive gewählten Zugriffscodes, um wiederum ein Symbol zu identifizieren, das von der Mobilstation gesendet wird, der der gewählte Zugriffscode zugewiesen ist, und nach jeder Iteration Erzeugen von weiter modifizierten gespeicherten Abtastwerten zur Verarbeitung in der nächsten Iteration.

41. Verfahren nach Anspruch 40, wobei die Zugriffscodes in einer abfallenden Reihenfolge einer empfangenen Signalstärke der entsprechenden Mobilstation, der der Zugriffscode zugewiesen ist, gewählt werden.

Revendications

1. Système de communication comprenant une pluralité de stations mobiles et une station de base améliorée pour recevoir des signaux depuis lesdites stations mobiles et décoder des signaux portant des informations émis à partir de celles-ci, la station de base comprenant :

a) des moyens formant antenne (20 à 22) comprenant des éléments d'antenne (22) disposés autour d'une structure de support (21) pour recevoir des signaux émis depuis ladite pluralité de stations mobiles et générer des signaux de sortie (23) à partir de chaque élément d'antenne (22) ;
b) des moyens de conversion (30, 31) pour amplifier (311, 315), filtrer (310, 312, 314), et convertir (316) des signaux venant de chacun desdits éléments d'antenne (22) en un nombre correspondant de signaux convertis (36), pour le traitement ;
c) des moyens de mémorisation pour mémoriser temporairement un certain nombre d'échantillons desdits signaux convertis (36) à des instants successifs dans le temps ; et
d) des moyens de traitement (70, 71) pour traiter et retraiter successivement de façon itérative lesdits échantillons mémorisés afin de décoder ladite information venant de chacune desdites stations mobiles tour à tour, dans lequel le traitement assuré par lesdits moyens de traitement identifie à partir desdits échantillons mémorisés un symbole d'information émis par l'une desdites stations mobiles, de façon à décoder par conséquent ledit signal portant une information, et soustrait des valeurs en fonction dudit symbole d'information identifié venant desdits échantillons mémorisés de tous les signaux d'éléments d'antenne, de façon à réduire par con-

séquent l'interférence entre le signal qui vient d'être décodé et le signal devant être décodé lors d'une itération suivante.

2. Système de communication selon la revendication 1, dans lequel au moins certaines des stations mobiles émettent ladite information en utilisant le même canal de fréquence radio au même moment.

3. Système de communication selon la revendication 1, dans lequel au moins certaines desdites stations mobiles émettent des signaux d'accès multiple à division de code.

4. Système de communication selon la revendication 1, dans lequel lesdits moyens de traitement comprennent de plus :

   des moyens pour combiner des échantillons correspondants parmi lesdits échantillons mémorisés convertis à partir d'éléments d'antenne respectifs afin de renforcer les signaux reçus depuis une direction particulière, dans laquelle se trouve une station particulière parmi lesdites stations mobiles.

5. Système de communication selon la revendication 1, dans lequel lesdits signaux décodés successivement sont sélectionnés dans l'ordre descendant de force de signal reçu.

6. Système de communication selon la revendication 4, dans lequel lesdits moyens pour la combinaison calculent une somme pondérée des valeurs combinées en utilisant comme poids un jeu de coefficients de formation de faisceau complexes.

7. Système de communication selon la revendication 6, dans lequel lesdits coefficients de formation de faisceau sont adaptés lors de chaque itération pour renforcer le signal qui est décodé lors de cette itération.

8. Système de communication selon la revendication 1, dans lequel lesdits moyens de traitement comprennent :

   des moyens de formation de faisceau pour combiner des groupes desdits échantillons mémorisés comprenant un échantillon de signal converti par lesdits moyens de conversion à partir de chaque antenne au même instant dans le temps afin de produire des échantillons de faisceaux pour des signaux reçus depuis une pluralité de directions d'arrivée à un instant correspondant dans le temps.

9. Système de communication selon la revendication 8, comprenant de plus : des moyens de dé-étalement d'accès multiple à division de code pour traiter lesdits échantillons de faisceaux reçus à des instants successifs dans le temps à partir de la même direction parmi ladite pluralité de directions d'arrivée dans l'ordre afin d'identifier ledit symbole identifié émis à partir de l'une desdites stations mobiles et reçu sur ladite station de base améliorée depuis ladite direction d'arrivée.

10. Système de communication selon la revendication 9, dans lequel lesdits moyens de dé-étalement d'accès multiple à division de code comprennent le calcul d'une transformation de Walsh-Hadamard afin d'obtenir un certain nombre de composantes de spectre de Walsh, correspondant chacune à l'un d'un alphabet de symboles d'information autorisé.

11. Système de communication selon la revendication 10, dans lequel ledit symbole identifié est identifié en déterminant la plus grande desdites composantes de spectre de Walsh, et, par conséquent le symbole correspondant, parmi ledit alphabet de symboles autorisé.

12. Système de communication selon la revendication 11, dans lequel ladite composante de spectre de Walsh la plus grande est établie à zéro après qu'il a été déterminé qu'elle était la plus grande.

13. Système de communication selon la revendication 12, dans lequel ledit spectre de Walsh après que ladite composante la plus grande a été établie à zéro est transformé selon une transformation de Walsh-Hadamard inverse afin d'obtenir des échantillons de faisceaux modifiés.

14. Système de communication selon la revendication 13, dans lequel lesdits échantillons de faisceaux modifiés sont combinés à l'aide de moyens de formation de faisceau inverses afin d'obtenir des échantillons mémorisés modifiés qui remplacent les échantillons originaux parmi lesdits échantillons mémorisés avant d'effectuer une itération sui-

vante pour décoder un symbole à partir d'un émetteur mobile différent.

15. Système de communication selon la revendication 1, dans lequel ladite station de base améliorée est adaptée pour recevoir lesdits signaux émis à partir desdites stations mobiles, chacun à l'aide d'un code d'accès assigné (14), dans lequel lesdits moyens de traitement sont adaptés pour agencer lesdits échantillons reçus en séquence dans le temps depuis lesdits éléments d'antenne dans un groupement espace/temps à deux dimensions, une dimension de celui-ci correspondant aux différents éléments d'antenne et l'autre dimension correspondant au temps de réception, et pour décrypter les échantillons numériques mémorisés à l'aide de l'un desdits codes d'accès assignés à une première desdites stations mobiles, et comprend : des moyens de transformation numérique à deux dimensions (71) pour traiter lesdits échantillons mémorisés décryptés afin de produire un groupement espace/code à deux dimensions d'échantillons transformés, la dimension d'espace dudit groupement espace/code à deux dimensions correspondant aux différentes directions d'arrivée possibles de signaux sur ladite station de base, émis par ladite première station mobile, et la dimension de code dudit groupement à deux dimensions correspondant aux symboles d'information dans un alphabet de symboles autorisé, dans lequel les échantillons transformés pour une valeur de direction d'arrivée fixe de la dimension d'espace indiquent les corrélations avec les différents symboles d'information le long de la dimension de code.

16. Système de communication selon la revendication 1, dans lequel ledit code d'accès utilisé est choisi de façon à être celui assigné à la station mobile qui est reçue avec la plus grande force de signal sur ladite station de base.

17. Système de communication selon la revendication 15, **caractérisé par** des moyens de décodage pour le décodage de l'un desdits symboles d'information, comprenant des moyens de détermination pour déterminer le plus grand desdits échantillons transformés et identifier par conséquent un symbole appartenant audit alphabet de symboles autorisé, ainsi qu'une direction d'arrivée du signal, dans lequel ledit symbole d'information a été codé.

18. Système de communication selon la revendication 15, **caractérisé par** des moyens de décodage pour ledit décodage de l'un desdits symboles d'information, comprenant des moyens de combinaison pour combiner lesdits échantillons transformés qui se trouvent au voisinage de la dimension de direction d'arrivée à l'aide d'un jeu de coefficients de combinaison afin de produire une valeur combinée pour chaque position dans l'autre dimension dudit groupement à deux dimensions d'échantillons transformés.

19. Système de communication selon la revendication 18, **caractérisé par** des moyens de détermination pour déterminer la plus grande desdites valeurs combinées et identifier par conséquent ledit symbole d'information décodé.

20. Système de communication selon la revendication 17, dans lequel le plus grand desdits échantillons transformés est établi à zéro après l'identification dudit symbole.

21. Système de communication selon la revendication 20, comprenant de plus : des moyens de transformation à deux dimensions inverses (71) pour transformer lesdits échantillons transformés comportant un échantillon établi à zéro afin d'obtenir des échantillons mémorisés modifiés mémorisés dans lesdits moyens de mémorisation (70).

22. Système de communication selon la revendication 21, **caractérisé par** des moyens (71) pour traiter lesdits échantillons mémorisés modifiés à l'aide desdits moyens de transformation à deux dimensions avec le code d'accès assigné à une deuxième station mobile, et identifier par conséquent un symbole émis par ladite deuxième station mobile.

23. Système de communication selon la revendication 22, dans lequel, après l'identification du symbole émis par ladite deuxième station mobile, une composante de transformation correspondante est établie à zéro, après quoi la réalisation de ladite transformation à deux dimensions inverse est effectuée afin de produire d'autres échantillons mémorisés modifiés.

24. Système de communication selon la revendication 23, dans lequel lesdits autres échantillons modifiés sont traités de façon itérative à l'aide de codes d'accès sélectionnés successivement afin d'identifier successivement des symboles émis par des stations mobiles auxquelles sont assignés lesdits codes d'accès, et, après l'identification de chaque symbole, afin de modifier à nouveau lesdits échantillons mémorisés en établissant à zéro une composante transformée et en réalisant une transformation inverse.

25. Système de communication selon la revendication 24, dans lequel lesdits codes d'accès sélectionnés successi-

vement sont assignés à des stations mobiles reçues sur ladite station de base dans un ordre de force de signal successivement descendant.

26. Système de communication selon la revendication 15, **caractérisé en ce que** lesdits moyens de transformation numérique à deux dimensions (71) effectuent ledit traitement desdits échantillons mémorisés à l'aide de moyens de transformation numérique à décalage dans le temps prescrit (71) qui sont présents entre les échantillons corrélés et lesdits symboles d'information ; ladite répétition de ladite transformation à deux dimensions pour une pluralité desdits décalages dans le temps correspondant à la réception retardée de signaux depuis ladite première station mobile, correspondant à des échos retardés desdits signaux provoqués par la réflexion de signaux à partir d'objets dans le trajet de propagation.

27. Système de communication selon la revendication 26, **caractérisé par** des moyens (73) pour prédire la direction d'arrivée et le temps d'arrivée correspondant de chacun desdits échos de force significative et pour adapter à ceux-ci lesdites différentes directions d'arrivée possibles prises par lesdits moyens de transformation numérique à deux dimensions et lesdits décalages dans le temps prescrits utilisés pour la corrélation.

28. Système de communication selon la revendication 27, **caractérisé par** des moyens de combinaison (74) pour combiner l'utilisation d'un jeu de composantes transformées par des coefficients de pondération correspondant auxdites directions et auxdits temps d'arrivée prédits afin d'obtenir un jeu de valeurs combinées correspondant à la corrélation avec chaque symbole dans ledit alphabet de symboles autorisé.

29. Système de communication selon la revendication 28, **caractérisé par le fait que** l'une desdites valeurs combinées qui a la plus grande valeur est déterminée, et identifie par conséquent un symbole émis par ladite première station.

30. Système de communication selon la revendication 29, **caractérisé par** des moyens (74) pour établir à zéro des composantes transformées à deux dimensions correspondant audit symbole identifié et correspondant auxdites directions et auxdits temps d'arrivée prédits, et transformer par une transformation inverse lesdites composantes transformées après l'établissement à zéro de ladite composante correspondant au symbole, au temps et à la direction afin d'obtenir des valeurs d'échantillons mémorisées modifiées.

31. Système de communication selon la revendication 30, **caractérisé par** des moyens (74) pour retraiter de façon itérative lesdits échantillons mémorisés modifiés à l'aide de codes d'accès sélectionnés successivement pour identifier tour à tour un symbole émis par la station mobile à laquelle a été assigné le code d'accès sélectionné, et, après chaque itération, pour générer d'autres échantillons mémorisés encore modifiés pour le traitement dans l'itération suivante.

32. Système de communication selon la revendication 31, **caractérisé en ce que** lesdits codes d'accès sont sélectionnés dans un ordre descendant de force de signal reçu de la station mobile correspondante à laquelle est assigné le code d'accès.

33. Procédé pour recevoir des signaux émis à partir d'une pluralité de stations mobiles, dans un système de communication comprenant lesdites stations mobiles et une station de base améliorée, chaque signal étant reçu à l'aide d'un code d'accès respectivement assigné (14) et dudit code d'accès utilisé pour décoder des symboles d'information appartenant à un alphabet de symboles autorisé codé dans lesdites émissions, comprenant les étapes suivantes :

a) la réception de signaux émis depuis ladite pluralité de stations mobiles sur des moyens formant antenne (20 à 22) avec des éléments d'antenne (22) disposés autour d'une structure de support (21) et la génération de signaux de sortie (23) à partir de chaque élément d'antenne (22) ;
b) l'amplification (311, 315), le filtrage (310, 312, 314), et la conversion (316) de signaux venant de chacun desdits éléments d'antenne (22) en un nombre correspondant de signaux convertis (36) pour le traitement ;
c) la mémorisation temporaire d'un certain nombre d'échantillons (36) desdits signaux convertis à partir de chacun desdits éléments d'antenne (22) à des instants successifs dans le temps (t1, ..., t128) ;
d) le traitement par des moyens (70, 71), pour effectuer un traitement et un retraitement itératifs successifs, desdits échantillons mémorisés afin de décoder ladite information venant de chacune desdites stations mobiles tour à tour, dans lequel le traitement assuré par lesdits moyens de traitement identifie à partir desdits échantillons mémorisés un symbole d'information émis par l'une desdites stations mobiles, de façon à décoder par conséquent ledit signal portant une information, et soustrait des valeurs dépendant dudit symbole d'infor-

mation identifié desdits échantillons mémorisés de tous les signaux d'éléments d'antenne, de façon à réduire par conséquent l'interférence entre le signal qui vient d'être décodé et le signal qui doit être décodé lors d'une itération suivante.

34. Procédé selon la revendication 33, dans lequel ladite station de base améliorée est adaptée pour recevoir lesdits signaux émis à partir desdites stations mobiles, chacun à l'aide d'un code d'accès assigné (14), comprenant de plus les étapes d'agencement (71) desdits échantillons reçus en séquence dans le temps à partir desdits éléments d'antenne dans un groupement espace/temps à deux dimensions, une dimension de celui-ci correspondant aux différents éléments d'antenne et l'autre dimension correspondant au temps de réception, de décryptage (71) des échantillons numériques mémorisés à l'aide de l'un desdits codes d'accès assignés à une première station parmi lesdites stations mobiles, et de traitement (71) desdits échantillons mémorisés décryptés afin de produire un groupement espace/code à deux dimensions d'échantillons transformés, la dimension d'espace dudit groupement espace/code à deux dimensions correspondant à différentes directions d'arrivée possibles de signaux sur ladite station de base, émis par ladite première station mobile, et la dimension de code dudit groupement à deux dimensions correspondant aux symboles d'information dans un alphabet de symboles autorisé, dans lequel les échantillons transformés pour une valeur de direction d'arrivée fixe de la dimension d'espace indiquent les corrélations avec les différents symboles d'information le long de la dimension de code.

35. Procédé selon la revendication 34, **caractérisé en ce que** ledit traitement (71) est effectué en utilisant un décalage dans le temps prescrit entre les échantillons corrélés et lesdits symboles d'information ; et

en répétant ladite transformation à deux dimensions pour une pluralité desdits décalages dans le temps correspondant à une réception retardée de signaux depuis ladite première station mobile correspondant à des échos retardés desdits signaux provoqués par la réflexion de signaux à partir d'objets dans le trajet de propagation.

36. Procédé selon la revendication 35, comprenant de plus les étapes suivantes : la prédiction (73) de la direction d'arrivée et du temps d'arrivée correspondant de chacun desdits échos de force significative et pour adapter à ceux-ci lesdites différentes directions d'arrivée possibles assumées par lesdits moyens de transformation numérique à deux dimensions et lesdits décalages dans le temps prescrits utilisés pour la corrélation.

37. Procédé selon la revendication 36, comprenant de plus les étapes suivantes : la combinaison (74), à l'aide d'un jeu de composantes transformées par des coefficients de pondération correspondant auxdites directions et auxdits temps d'arrivée prédits, afin d'obtenir un jeu de valeurs combinées correspondant à une corrélation avec chaque symbole dans ledit alphabet de symboles autorisé.

38. Procédé selon la revendication 37, dans lequel l'une desdites valeurs combinées qui a la plus grande valeur est déterminée, et identifie par conséquent un symbole émis par ladite première station.

39. Procédé selon la revendication 38, comprenant de plus les étapes suivantes : l'établissement à zéro de composantes transformées à deux dimensions correspondant audit symbole identifié et correspondant auxdites directions et auxdits temps d'arrivée prédits et la transformation par une transformation inverse desdites composantes transformées après l'établissement à zéro de ladite composante correspondant à un symbole, à un temps et à une direction afin d'obtenir des valeurs d'échantillons mémorisées modifiées.

40. Procédé selon la revendication 39, comprenant de plus les étapes suivantes : le retraitement itératif desdits échantillons mémorisés modifiés à l'aide de codes d'accès sélectionnés successivement afin d'identifier tour à tour un symbole émis par la station mobile à laquelle est assigné le code d'accès sélectionné, et, après chaque itération, la génération d'autres échantillons mémorisés modifiés pour le traitement lors de l'itération suivante.

41. Procédé selon la revendication 40, dans lequel lesdits codes d'accès sont sélectionnés dans l'ordre descendant de force de signal reçu de la station mobile correspondante à laquelle est assigné le code d'accès.

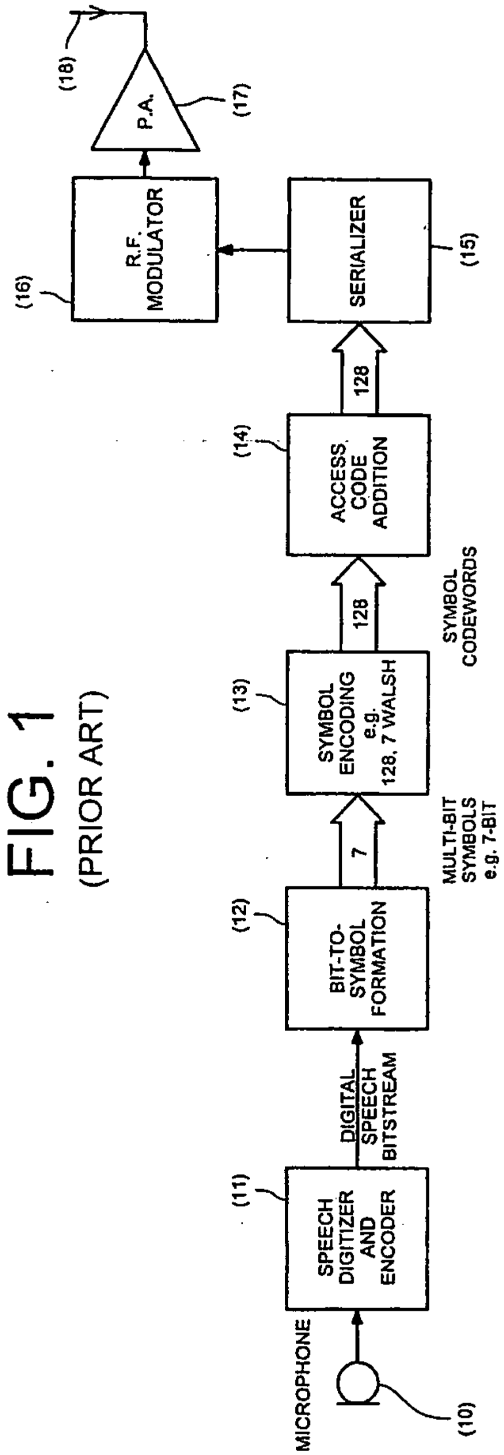


FIG. 1
(PRIOR ART)

FIG. 2

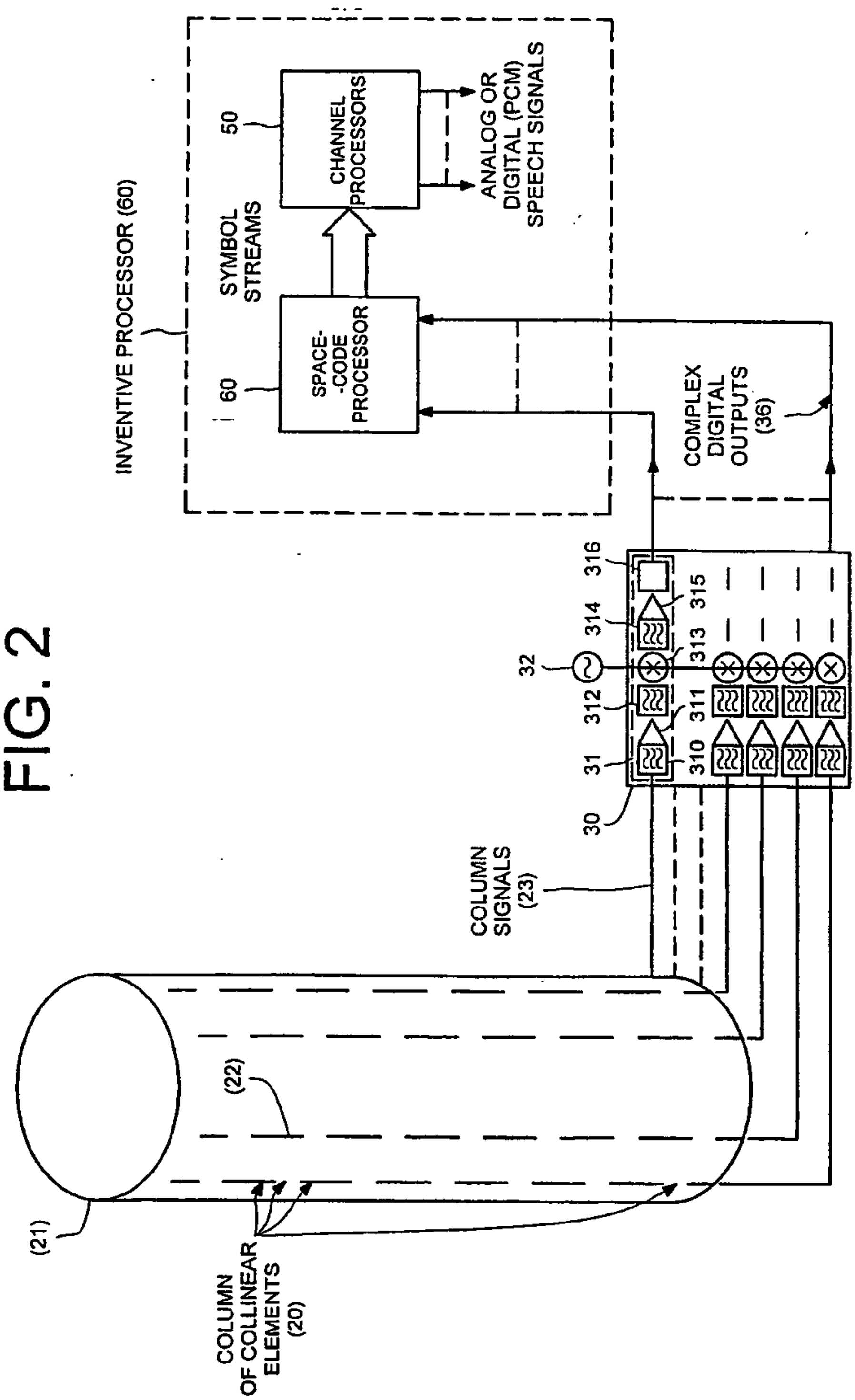

INVENTIVE PROCESSOR (60)
60
SPACE-
-CODE
PROCESSOR
SYMBOL
STREAMS
50
CHANNEL
PROCESSORS
ANALOG OR
DIGITAL (PCM)
SPEECH SIGNALS
COMPLEX
DIGITAL
OUTPUTS
(36)
32
316
314
315
313
312
311
31
310
30
COLUMN
SIGNALS
(23)
(22)
(21)
COLUMN
OF COLLINEAR
ELEMENTS
(20)

FIG. 3

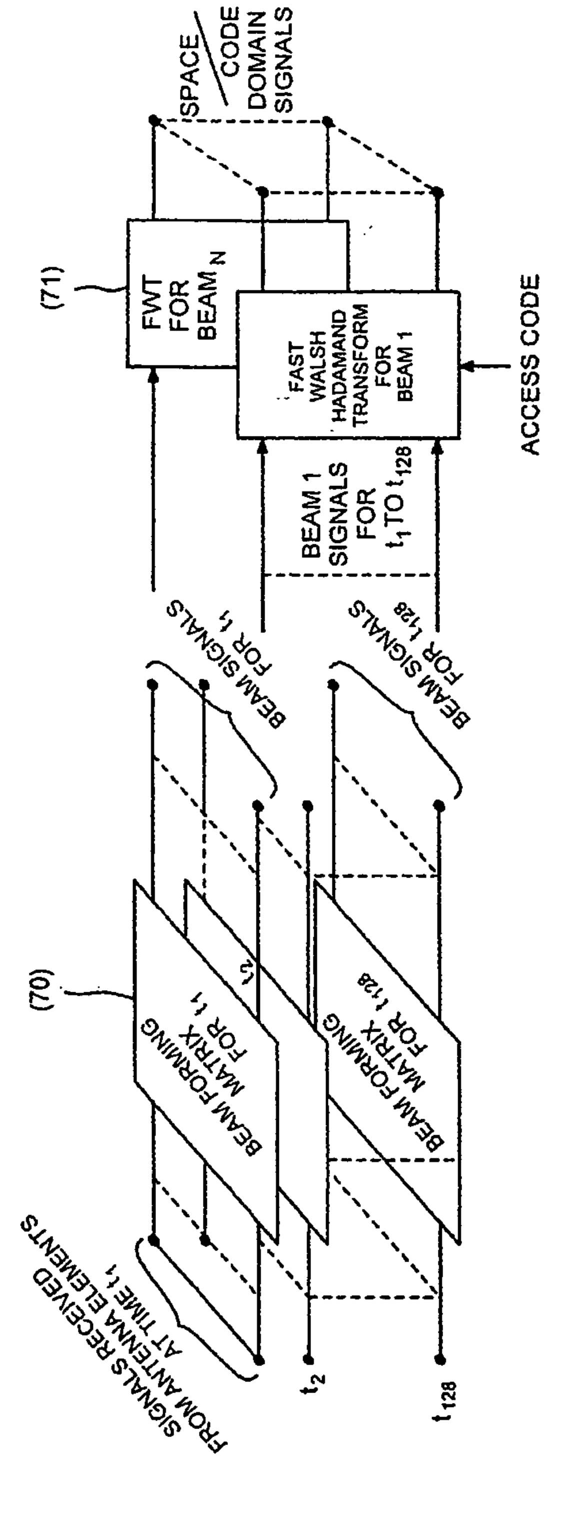

SIGNALS RECEIVED FROM ANTENNA ELEMENTS AT TIME t_1
t_2
t_{128}
(70)
BEAM FORMING MATRIX FOR t_1
t_2
BEAM FORMING MATRIX FOR t_{128}
BEAM SIGNALS FOR t_1
BEAM SIGNALS FOR t_{128}
BEAM 1 SIGNALS FOR t_1 TO t_{128}
(71)
FWT FOR BEAM $_N$
FAST WALSH HADAMAND TRANSFORM FOR BEAM 1
ACCESS CODE
SPACE / CODE DOMAIN SIGNALS

FIG. 4

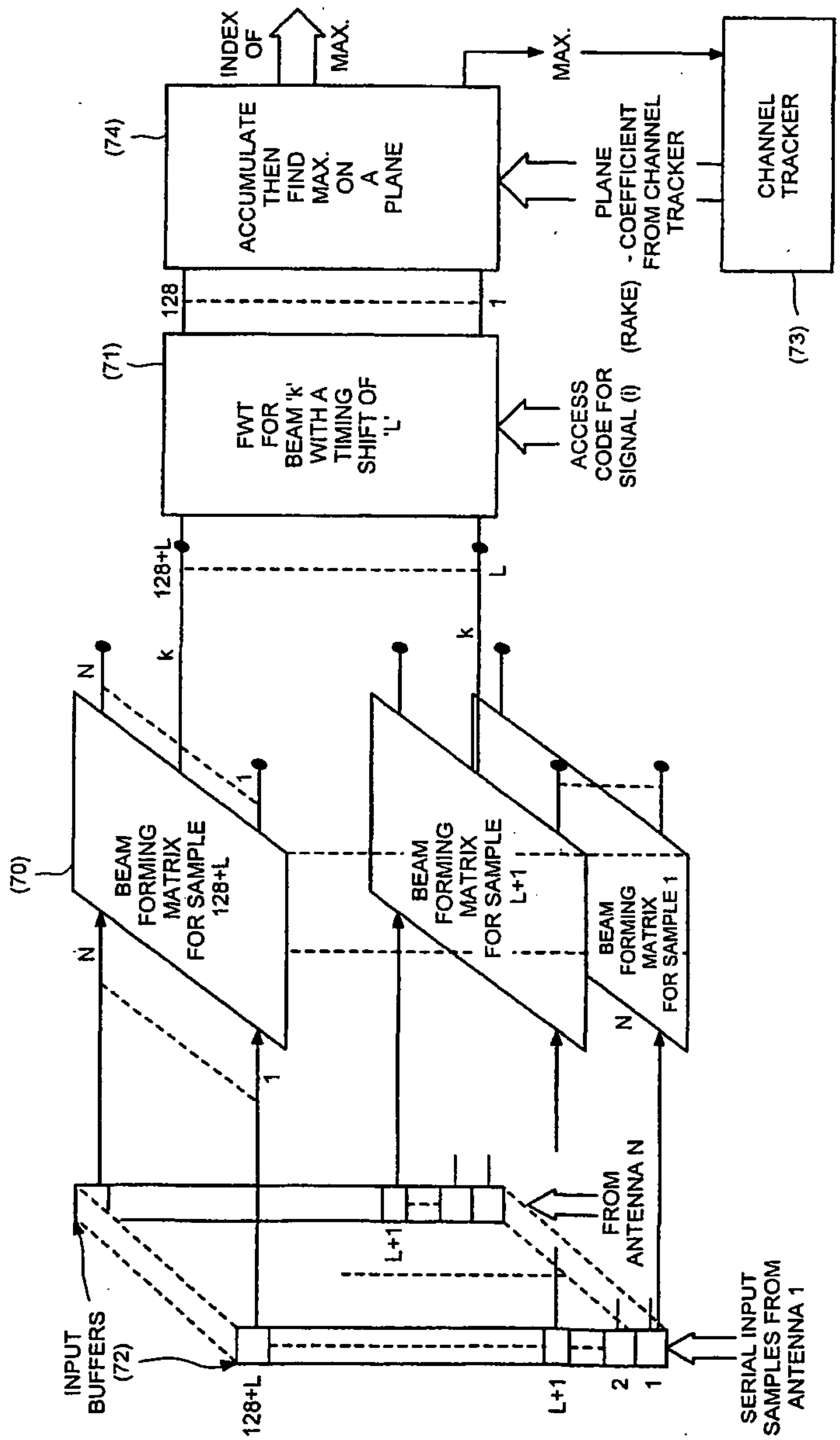
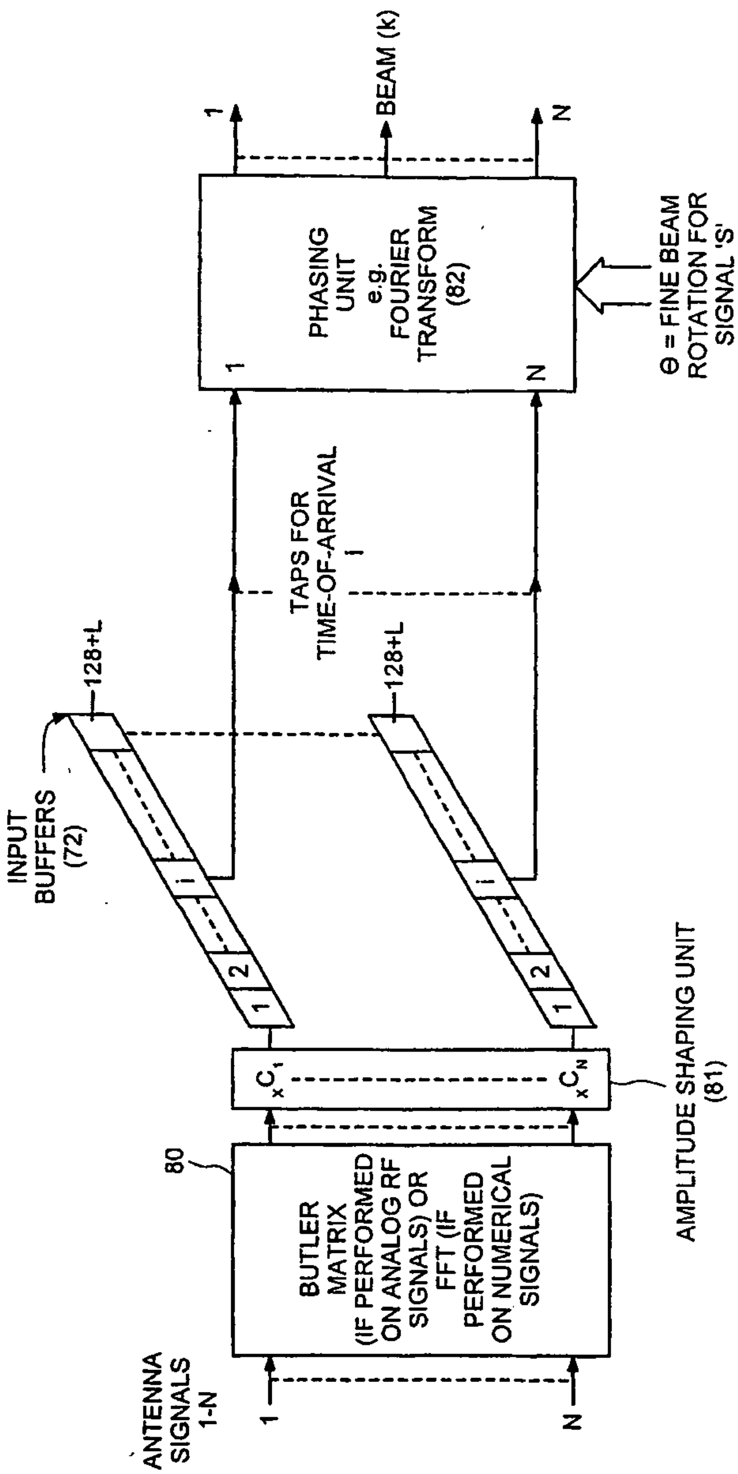

INPUT BUFFERS (72)
128+L
L+1
2
1
SERIAL INPUT SAMPLES FROM ANTENNA 1
FROM ANTENNA N
N
1
(70)
BEAM FORMING MATRIX FOR SAMPLE 128+L
BEAM FORMING MATRIX FOR SAMPLE L+1
BEAM FORMING MATRIX FOR SAMPLE 1
k
128+L
L
(71)
FWT FOR BEAM 'k' WITH A TIMING SHIFT OF 'L'
ACCESS CODE FOR SIGNAL (i)
128
(74)
ACCUMULATE THEN FIND MAX. ON A PLANE
INDEX OF MAX.
MAX.
(RAKE) PLANE - COEFFICIENT FROM CHANNEL TRACKER
CHANNEL TRACKER
(73)

FIG. 5


ANTENNA SIGNALS 1-N
1
N
BUTLER MATRIX (IF PERFORMED ON ANALOG RF SIGNALS) OR FFT (IF PERFORMED ON NUMERICAL SIGNALS)
80
AMPLITUDE SHAPING UNIT (81)
xC1
xCN
INPUT BUFFERS (72)
1
2
i
128+L
TAPS FOR TIME-OF-ARRIVAL i
PHASING UNIT e.g. FOURIER TRANSFORM (82)
1
N
Θ = FINE BEAM ROTATION FOR SIGNAL 'S'
BEAM (k)